SCIENCE SCOPE

SUMMER 2013 ▪ VOLUME 36 ▪ NUMBER 9

Discourse and Argumentation

• The negotiation cycle
• Assessing student arguments
• Evaluating the strength of evidence

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Rick Bounds
Publisher
David Beacom
Executive Director
David L. Evans
Advertising
Jason Sheldrake
Director
jsheldrake@nsta.org; 703-312-9273

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EDITOR’S ROUNDTABLE

Nurturing argumentation and discourse

Argument and discourse are central to the work of scientists as well as to the advancement of science. The practice of engaging in argument from evidence is included in A Framework for K–12 Science Education and the Next Generation Science Standards to improve students’ critical thinking and reasoning abilities and to deepen their understanding of science concepts and the nature of science (NRC 2012, Achieve Inc. 2013).

Unfortunately, as Taking Science to School points out, argumentation is rarely part of our classroom instruction (Duschl, Schweingruber, and Shouse 2007). While some teachers may not be comfortable departing from traditional teacher-dominated interactions where straightforward questions are asked seeking expected answers from students, science instruction must change to conform more closely to the now-established Framework and NGSS.

This issue of Science Scope contains an excellent collection of articles on the subject of argumentation and discourse that provides specific information to help you begin to implement this essential component of NGSS. Several of the articles also provide information for teachers about setting expectations and norms in the classroom employment of argumentation and discourse.

I would like to add some observations from years of trial and error with implementing student-to-student interactions and argumentation in my own teaching:

• Getting middle school students to understand the difference between scientific argument and “talk,” and everyday argument and “talk” is not easy! It requires patience and persistence to establish and maintain explicit but nonthreatening discourse guidelines that promote student responsibility, tolerance, and the use of evidence and scientific language.
• Since most of your students have had little foundational experience with argumentation and discourse in the earlier grades, many of them will not immediately master these skills; but just because they don’t seem to be making adequate progress, you should not abandon your efforts, nor allow yourself to revert to the more comfortable, traditional, initiate-response-evaluate format of teacher-student interaction.
• Stay the course! Teach students the elements of a sound argument and insist that they use them in classroom writing and speaking. Give constructive feedback often, design improvement exercises, and always encourage all students, not just the more assertive or vocal, to participate and become proficient in discourse and argumentation skills.
• Students must be provided with frequent opportunities to practice argumentation and discourse. Do not simply end lab activities and research projects by collecting lab reports to be graded and returned to individual students or by having a regimented, ubiquitous presentation of results: Reach for wider student learning by requiring students to engage in non-teacher-mediated, peer-to-peer talk or debate that uses evidence from their labs or research.

(continued on page 5)
Students love to talk in class, but channeling their passion for informal communication into the practice of engaging in argument from evidence can be very challenging. Learn how you can introduce this Next Generation Science Standards practice with the strategies and activities in this issue of Science Scope.

Turning the Science Classroom Into a Courtroom: Engaging in Argument from Evidence
Put Goldilocks on trial to demonstrate the importance of stating a claim and defending it with supportive evidence.
Douglas Llewellyn and Amanda Adams

Helping Students Evaluate the Strength of Evidence in Scientific Arguments: Thinking About the Inferential Distance Between Evidence and Claims
Examine a predator-prey relationship to remind students to consider the evidence before making an inference.
Lauren Brodsky, Andrew Falk, and Kevin Beals

The Practice of Critical Discourse in Science Classrooms
Engage students in science and engineering by providing opportunities for them to engage in conversation, critical discourse, and argumentation.
Kenneth L. Huff and Rodger W. Bybee

Crushing Soda Cans: A Novel Way for Students to Explore Energy
Explore how the potential or kinetic energy of an object affects the force the object is capable of exerting on another.
James Concannon, Patrick Brown, Laura Stumpe, and Elise Bartley
A Negotiation Cycle to Promote Argumentation in Science Classrooms
Cycle through the steps of a strategy for reaching a classroom consensus through argumentation.
_YS.-Chih Chen and Joshua Steenhoek_

Assessing Students’ Arguments: How Strong Are Their Justifications?
Present arguments about whether or not a dam should be built that would affect an indigenous people.
_Amanda M. Knight and Kris Grymonpré_

Show Me the Evidence! Scientific Argumentation in the Middle School Classroom
Learn how to focus classroom discussions on the validity of evidence-based scientific explanations of phenomena.
_Jennifer C. Mesa, Rose M. Pringle, and Lynda Hayes_

Let’s Talk Science: Seeding Argumentation About Cells and Growth
Engage students in a shared discourse about whether or not a seed is alive.
_Deena Gould_

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In my opinion, you must establish a positive learning environment in your classroom because it is the most essential aspect of effecting successful, large-scale student participation in classroom argumentation and discourse. From the beginning of the school year, work to build caring relationships with your students and an atmosphere of trust, fairness, and emotional safety in your classroom. In such a community, students will feel respected, nurtured, and supported and, over time, will become confident and comfortable taking risks and participating in discourse and argumentation without fear of ridicule or humiliation from fellow students or from being “shut down” by you, their teacher.

If you would like further information, inspiration, and pedagogical context about this practice, I recommend that you read the argumentation-related sections of the Framework and NGSS, as well as chapters 7 and 9 in Taking Science to School.

Inez Liftig
Editor, Science Scope

References

Science Scope 2014 Call for Papers

Below is a list of Science Scope’s upcoming themes for the 2014 calendar year. For more information on specific themes, please visit www.nsta.org/publications/call-scope.aspx. Don’t see a theme that matches your idea for an article? Not a problem. Science Scope is always in need of general submissions to round out each issue. Author guidelines are available at www.nsta.org/publications/journals.aspx#authors. When you are ready to submit your manuscript, please visit Manuscript Central at http://mc.manuscriptcentral.com/nsta. If you have any questions, please contact the Editor, Inez Liftig (zenisci8@aol.com), to discuss your article ideas, or Managing Editor Ken Roberts (kroberts@nsta.org) for information on submitting your manuscript.

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A tongue made for mopping

Nectar-feeding bats and busy janitors have at least two things in common: They want to wipe up as much liquid as they can as fast as they can, and they have specific equipment for the job. A study describes the previously undiscovered technology employed by the bat *Glossophaga soricina*: a tongue tip that uses blood flow to erect scores of little hairlike structures at exactly the right time to slurp up extra nectar from within a flower.

The bat’s “hemodynamic nectar mop,” as the paper dubs the tongue tip, features speed and reliability that industrial designers might envy, said lead author Cally Harper, a graduate student at Brown University. As a matter of what nature can evolve, she said, the tongue tip is surprisingly clever.

The bat’s cylindrical tongue has a mesh of muscle fibers that contract so that the tongue becomes thinner but longer (extending farther into the flower). The same muscle contraction simultaneously squeezes blood into the tiny hairlike papillae. As blood is displaced to the tongue tip, the papillae flare out perpendicular to the axis of the tongue. In their erect state, they not only add exposed surface area but also width, allowing the tongue to function as a highly effective nectar-gathering device.

The entire extension and retraction of the tongue tip occurs within an eighth of a second. Hovering requires a lot of energy, so nectar-feeding bats must get a lot of calories quickly for it to be worthwhile. It is not known if other nectar-feeding bats also have blood-activated papillae on their similar-looking tongues. Other species such as hummingbirds and bees employ different rapid means of morphing their tongues for improved nectar feeding. Perhaps these highly evolved designs will inspire future technology.

Neptune’s discovery commemorated

On May 16, 2013, Neptune arrived at the same location in space where it was discovered nearly 165 years ago. To commemorate the event, NASA’s Hubble Space Telescope shared “anniversary pictures” of the blue-green giant planet.

Neptune is the most distant major planet in our solar system. German astronomer Johann Galle discovered the planet on September 23, 1846. At the time, the discovery doubled the size of the known solar system. The planet is 2.8 billion mi. (4.5 billion km) from the Sun, 30 times farther than Earth. Under the Sun’s weak pull at that distance, Neptune plods along in its huge orbit, slowly completing one revolution approximately every 165 years. The giant planet experiences seasons just as Earth does, because it is tilted 29 degrees, similar to Earth’s 23-degree tilt. Instead of lasting a few months, each of Neptune’s seasons continues for about 40 years.

In the Hubble images, absorption of red light by methane in Neptune’s atmosphere gives the planet its distinctive aqua color. The clouds are tinted pink because they are reflecting near-infrared light. A faint, dark band near the bottom of the southern hemisphere is probably caused by a decrease in the hazes in the atmosphere that scatter blue light.

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Tiny, but powerful: The nanoscale

by Janna Palliser

Most of us have a vague idea of what “nanotechnology” is—something to do with the manipulation of very, very small things for scientific or medical purposes. Formally, nanotechnology is defined as “the understanding and control of matter at dimensions between approximately 1 and 100 nanometers (the nanoscale), where unique phenomena enable novel applications” (NSET and NEHI 2011). Nanotechnology began about 30 years ago and has expanded greatly in the past decade or so. Today, nanomaterials (substances broken down into molecule-size particles) are used in a wide variety of products, from sporting equipment and automotive parts to cosmetics, sunscreens, and medical devices (NNIa; Strom 2013). This month’s column will explore the evolving world of nanotechnology.

Nanotechnology basics

Nanotechnology involves imaging, measuring, modeling, and manipulating matter at the nanoscale. A nanometer is one billionth of a meter. For comparison, a piece of paper is about 100,000 nanometers thick (NSET and NEHI 2011). Figure 1 provides measurements of some nanoscale objects.

Nanomaterials have unique physical and chemical properties (different conductivity, optical sensitivity, and reactivity), which originate mainly from their small size, surface structure, chemical composition, shape, solubility, and aggregation. Gases, liquids, and solids can exhibit unusual properties at the nanoscale; some can become stronger, other can become better of heat and electricity, for example. Other materials may become more chemically reactive, reflect light better, or change color as their size or structure is changed (NNIa). Various technologies and industries make use of these unique properties (EPA).

Applications

With nanotechnology, the essential structure of materials can be tailored to achieve specific properties. Materials can be made stronger, lighter, more durable, more reactive, more sieve-like, or better electrical conductors. Nanoparticles are already found in thousands of consumer products, including cosmetics, pharmaceuticals, antimicrobial infant toys, sports equipment, food packaging, and electronics (Deardorff 2012). Current applications of nanotechnology include the following:

• “nanoscale additives for baseball bats, tennis rackets, motorcycle helmets, automobile bumpers, and luggage to make them lightweight and resilient;
• nanoscale additives on fabrics to help resist wrinkling, staining, and bacterial growth;
• nanoscale thin films on eyeglasses, computer and camera displays, and windows to make them water-repellent, antireflective, antifog, antimicrobial, and scratch-resistant;
• nanoscale materials in cosmetic products to provide greater coverage, cleansing, and absorption;
• nanoscale materials in sunscreens, creams and lotions, shampoos, and makeup to enhance antioxidant and antimicrobial properties;
• nanocomposites in food containers to minimize carbon dioxide leakage out of carbonated beverages, moisture outflow, and the growth of bacteria;
• high-power rechargeable battery systems, thermoelectric materials for temperature control, lower-rolling-resistance tires, high-efficiency sensors and electronics, thin-film solar panels, and fuel additives for cleaner exhaust;
• faster and more efficient nanoscale transistors;
• magnetic random access memory to save encrypted data during a system shutdown or crash, enable resume-play features, and gather vehicle accident data;
• displays for new TVs, laptop computers, cell phones, and digital cameras that incorporate nanostructured polymer films to offer brighter images in a flat for-
mat, wider-viewing angles, lighter weight, lower power consumption, and longer lifetimes;

- flash memory chips for iPod Nanos; ultraresponsive hearing aids; antimicrobial or antibacterial coatings on mouse, keyboard, and cell phone casings; conductive inks for printed electronics for smart cards/smart packaging; more lifelike video games;

- semiconducting nanocrystals to enhance biological imaging for medical diagnostics;

- measuring the amount of an antibody-nanoparticle complex that accumulates in plaque to detect atherosclerosis; and

- using gold nanoparticles to detect early-stage Alzheimer’s disease (NNIb)."

**Environmental applications**

An Environmental Protection Agency (EPA) laboratory is developing benign nanomaterials to replace conventional catalysts (substances that initiate or speed up chemical reactions but do not themselves change during the reaction). Catalysts can be expensive and dangerous if not handled properly, and may end up as waste products that must be treated or disposed of carefully. Catalyst systems supported on nanoparticles have applications in water purification, the absorption
of heavy metals, and antibacterial coatings, and the potential to destroy noxious and toxic gases in automobile catalytic converters and in power generation systems that burn coal and gasoline (EPA 2011).

The EPA is also working on a new way to synthesize nanoparticles. Instead of using large energy inputs and toxic solvents to break down larger materials, nanomaterials are assembled at the molecular level. This approach avoids the use of hazardous reducing agents, and instead employs benign metallic salts (e.g., iron salts), water, and polyphenols from plant materials (tea, coffee, and red grapes) to act as reducing or capping agents to prevent nanomaterials from aggregating into larger clumps during the production process. Coated iron nanomaterials can be used in environmental remediation operations, to remove contaminants from groundwater, and to remove pesticides from soils near crops. The nanomaterials naturally degrade, so they can be left at remediation sites (EPA 2011).

Additional environmental applications and research include the following:

- “solar panels incorporating nanotechnology (more efficient than standard designs in converting sunlight to electricity);
- improved efficiency of fuel production from normal and low-grade raw petroleum materials through better catalysis, as well as fuel-consumption efficiency in vehicles and power plants through higher-efficiency combustion and decreased friction;
- nano-bioengineering of enzymes to enable conversion of cellulose into ethanol for fuel (from wood chips, corn stalks, unfertilized perennial grasses);
- batteries that are less flammable, quicker charging, more efficient, and lighter; have a higher power density; and hold electrical charge longer;
- various nanoscience-based options that convert waste heat in computers, automobiles, homes, and power plants to usable electrical power;
- an epoxy containing carbon nanotubes used to make windmill blades that are stronger and lighter to increase the amount of electricity that windmills can generate;
- wires containing carbon nanotubes with lower resistance than high-tension wires currently used in the electric grid (to reduce transmission power loss);
- thin-film solar electric panels that can be fitted onto computer cases and flexible nanowires woven into clothing to generate usable “on-the-go” energy from light, friction, or body heat;
- lighter and stronger vehicle chassis materials for the transportation sector;
- lower energy consumption in advanced electronics;
- low-friction nano-engineered lubricants for higher-efficiency machine gears, pumps, and fans;
- light-responsive smart coatings for glass to complement alternative heating/cooling schemes;
- filtration and purification of water;
- cleaning industrial water pollutants in groundwater through chemical reactions;
- a nanofabric “paper towel” woven from tiny wires of potassium manganese oxide that can absorb 20 times its weight in oil for clean-up applications; and
- air filters with nanotechnology-based filters that allow “mechanical filtration,” in which the fiber material creates nanoscale pores that trap particles larger than the size of the pores (NNlb).”

**Concerns**

Health concerns with nanoparticles are being raised because nanoparticles can travel through the body more widely and enter cells more readily than larger particles. Little is known about whether nanoparticles in food pose risks, but nanoparticles can cause cell death (e.g, silver nanoparticles are used to kill bacteria) (Biello 2013).

Research on animals has found that inhaled nanoparticles can reach all areas of the respiratory tract; because of their small size and shape, nanoparticles can migrate quickly into cells and organs. Other animal studies have shown that some nanoscale materials can even cross the protective blood-brain barrier. There is also evidence that some nanoparticles could cause damage through oxidative stress (damage to a cell, tissue, or organ by reactive oxygen species such as free radicals) and other mechanisms if they reach the brain (Deardorff 2012). A recent UCLA study found that nanoparticles of titanium dioxide can damage and destroy DNA and chromosomes, a process linked to heart disease, brain diseases, and cancer (NRDC 2011).
Of 15 scientific studies conducted by government, industry, and independent researchers over the past decade, only one found that nanoparticles were absorbed by the skin of rabbits; none detected human skin penetration. Regarding nanoparticles in sunscreen, titanium dioxide and zinc oxide are the most effective at blocking UV rays when nanosize; alternative sunscreens containing organic chemicals such as oxybenzone and octinoxate can potentially mimic estrogen (estrogen may be implicated in breast-cancer risk) (Biello 2007).

Exposure to nanomaterials may occur unintentionally in the environment or through the use of products enhanced with nanotechnology. Nanomaterials released in the environment may undergo transformation from conditions such as temperature and salinity, habitat, and co-contaminants. These transformed nanomaterials could modify atmospheric, soil, or water chemistry (NNIc). Nano-titanium dioxide could pose a threat to aquatic systems. A study at Arizona State University found that nanosilver can wash off consumer products and enter the water supply. A Friends of the Earth report noted that antibacterial nanomaterials can endanger the good bacteria that both aquatic systems and wastewater treatment plants depend on (NRDC 2011). Research on nanotechnology and its impact on the environment and humans is ongoing (NNIc).

Nanotechnology and food
Nanomaterials are starting to enter the food chain (Strom 2013). One study found nanoparticles of titanium dioxide less than 10 nanometers in size in the powdered-sugar coating on doughnuts (perhaps due to the milling process of the powdered sugar). Of the 26 companies that responded to an industry survey, 10 were unsure whether or not their products contain nanoparticles (Biello 2013).

Regulations
The Food and Drug Administration (FDA) is creating a regulatory science program to address nanotechnology as an emerging technology. Nanomaterials developed using nanotechnology can have different chemical, physical, or biological properties than conventionally scaled materials used in products regulated by the FDA; new regulations governing the implementation of nanotechnology in the food and drug industries must be developed (FDA 2012).

This article addresses the following core idea from the K–12 Framework (NRC 2012, p. 212):
Core Idea ETS2: Links Among Engineering, Technology, Science, and Society
• ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World
Core Idea PS1: Matter and Its Interactions
• PS1.A: Structure and Properties of Matter

Conclusion
Nanotechnology is a new, booming, and promising technology. The potential applications available as a result of nanotechnology are exciting and could drastically and positively affect products and processes. Because the technology is new and rapidly evolving, more research is needed into the short- and long-term effects of nanomaterials on humans and the environment.

References
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• Bridging to the Highly Anticipated Next Generation Science Standards—What’s in It for Me?
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Resources
Intro to nano video—www.youtube.com/watch?v=GmUeCf_bI-s
K–12 resources—www.nisenet.org/community/k-12-teachers
Nanoze (for kids)—www.nanooze.org/main/Nanooze/English.html
Nanoscale Informal Science Education Network—http://nisenet.org
Project on Emerging Nanotechnologies—www.nanotechproject.org/topics/nano101

Janna Palliser (jpalliser@nsta.org) is consulting editor for Science Scope.
TURNING THE SCIENCE CLASSROOM INTO A COURTROOM

Engaging In Argument from Evidence

by Douglas Llewellyn and Amanda Adams
Every day, all of us, including middle-school-age youngsters, are besieged with unscrupulous claims backed by questionable evidence. Turn on the television, read the newspaper, or go online, and you can’t avoid someone making a claim to adults about how to lose weight, how to stop smoking, how to increase your financial investments, or the benefits of herbal medicines. For kids, it may be a basketball sneaker company that claims it will make them into a top athlete, or an energy drink that is guaranteed to give them more pep. To prevent middle-level students from being bamboozled into making false assumptions, teachers need to provide lessons that (a) help students analyze assertions and scoff at claims that lack compelling and empirical evidence and (b) instill in their students the ability to discern a deceiving scientific argument from one grounded in substantial evidence. Effective teachers do this, in part, by giving students the experience of stating a claim, then defending and justifying it with supportive evidence. This will help students, when faced with a claim, not to jump to conclusions. Rather, they should first ask the following: Is the claim realistic? How reliable is the evidence? Is the evidence compelling?

This article proposes a way to scaffold students toward an understanding of scientific argumentation by answering three questions:

1. What are the basic parts of a scientific argument?
2. What do the Common Core State Standards and A Framework for K–12 Science Education say about argumentation?
3. How can teachers help introduce students to the concept of making and defending arguments by turning the science classroom into a courtroom?

First, teachers need to explain to students that everyday home and school-yard arguing is not the same as a scientific argument. Unlike conventional arguments, where middle-level students engage in quarrels through their interactions with classmates and peers, scientific argumentation is a critical-
thinking skill that students apply to propose, support, critique, refine, justify, and defend their positions about issues relating to science (Llewellyn 2013). As Ross, Fisher, and Frey (2009) put it, “Children are often good at arguing, but not at argumentation” (p. 28).

Although scientific arguments can vary in form and fashion, they often involve six essential elements:

1. The question emanates from an observed phenomenon that generates a scientific investigation or debate.
2. The assumption is an initial statement that uses prior knowledge to describe or explain an observed phenomenon. Sometimes the assumption helps build a model that constructs a possible answer to the question being studied. The assumption can also lead to a proposed hypothesis, a tentative answer, or a possible solution to a problem.
3. The claim is an assertion or conclusion that attempts to answer the original question or summarize the findings of a scientific inquiry.
4. The evidence is extracted from all the data collected in the form of observations and measurements. The evidence supports the legitimacy of the stated claim.
5. The explanation summarizes the claim and provides an interpretation of the newly acquired knowledge.
6. The rebuttal is a discussion, coming from the presenter’s audience, that provides a counterclaim or new evidence to refute the original claim made.

These six elements play an important role in designing argument-based science investigations. Based on what scientists do and what we try to teach our students about scientific practices, argumentation is as inherent to scientific inquiry as it is to the nature of science.

As you scan down the lengthy list, notice how many standards include the terms claim, evidence, or explanation. Figure 1 illustrates that argumentation is a proficiency that intersects with many aspects of literacy. It tells us that by using the new benchmarks, classroom teachers can easily connect the standards of language arts and science to foster critical-thinking and problem-solving skills. Furthermore, argumentation is a 21st-century skill where students learn to (a) create and test their ideas, (b) design and conduct scientific inquiries, (c) collaborate with others throughout all phases of learning to argue and gather supporting evidence, (d) communicate clearly and articulately in presenting their findings and explanations, and (e) use information and media literacy to gather and use reliable sources to back their claims.

What does A Framework for K–12 Science Education say about argumentation?

The Common Core State Standards are not alone in citing argumentation as an important skill for students to acquire. In 2012, the National Research Council (NRC) produced the document A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. The Framework sets a vision for the future of science education and is built around three major dimensions: (1) scientific and engineering practices, (2) crosscutting concepts that unify science and engineering fields, and (3) core ideas in the physical sciences, life sciences, Earth and space sciences, and engineering and technology. As with the Common Core,
argumentation is one of the most essential features in the new Framework. The Framework makes a point of emphasizing “practices” as they relate to the authentic work of scientists and engineers. According to the NRC (2012), “the focus here is on important practices, such as modeling, developing explanations, and engaging in critique and evaluation (argumentation) that have too often been underemphasized in the context of science education” (p. 44). The Framework identifies eight essential practices to be integrated into the K–12 science curriculum that have a significant influence on inquiry and argumentation (NRC 2012, p. 42):

1. Asking questions
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics, information and computer technology, and computational thinking
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

FIGURE 1  Nanoscale measurements of various natural and human-made objects

Reading standards that apply to scientific argumentation
- Cite evidence that most strongly supports a point or analysis from the text.
- Distinguish between facts and opinions in a science-related article.
- Determine an author’s point of view or purpose in a chapter and respond with counterevidence or an alternative viewpoint.
- Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is sound and the evidence is relevant and sufficient.
- Analyze a case in which two or more sources provide conflicting information on the same topic and identify where the sources disagree on matters of fact or interpretation.

Writing standards that apply to scientific argumentation
- Support a claim with logical reasoning and relevant, accurate evidence that demonstrate an understanding of a science topic.
- Use scientific words and phrases to clarify the reasoning and relationships among claims, counterclaims, and evidence.
- Provide a concluding statement or explanation that follows from and supports the argument presented.
- Write arguments focused on discipline-specific content to support claims with clear reasons and relevant evidence.

- Introduce a claim about a topic or issue, acknowledge and distinguish the claim from alternate or opposing claims, and organize the reasons and evidence logically.
- Write informative explanations generated from scientific procedures and investigations.

Speaking and listening standards that apply to scientific argumentation
- Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.
- Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.
- Pose questions that connect the ideas of several speakers and respond to others’ questions and comments with relevant evidence, observations, and ideas.
- Acknowledge new information expressed by others and, when warranted, qualify or justify their own views in light of the evidence presented.
- Describe a speaker’s argument and specific claims, evaluating the soundness of the reasoning and relevance and sufficiency of the evidence and identify when irrelevant evidence is introduced.
You can see that Practices 6 and 7 apply directly to students’ understanding of how explanation, argument, and communication are closely related. Thus, by implementing the eight Framework practices in the school curriculum, science teachers can seamlessly integrate inquiry- and argument-based instruction.

**The classroom as a courtroom**

As the Common Core and Framework demonstrate, the current trend in science education emphasizes literacy- and argument-based lessons. Science teachers in the middle-level grades may wonder how to incorporate argumentation into their instructional methods. Questions asked by some of these educators include “How do I attempt to implement the integration of literacy and argumentation in my classroom?” and “How can I help students make and defend arguments in my science classroom?” We will now explore one option—turning the science classroom into a courtroom—as a way to build student awareness of and interest in argumentation. This is an “opening hook” intended for use by teachers to introduce the concept of argumentation and begin to establish a mind-set for argumentation in their students rather than a step-by-step lesson plan for teaching argumentation mechanics.

One way to introduce argumentation is by showing what argumentation looks like in familiar settings, such as a courtroom. Teachers can show video clips from movies and television series that illustrate what judicial argumentation looks like and plan follow-up discussions on the role of the judge, the prosecutor, the defense lawyer, and the jury. Students will begin to understand how people with different roles and viewpoints present evidence and testimony to prove a claim of guilt or innocence, while the jury renders a verdict based on the preponderance of the evidence.

Bringing the courtroom into the classroom allows teachers to explore the use of argumentation in courtroom proceedings and protocol as a means of building student interest in applying argumentation in the science classroom. As a first step in turning your classroom into a courtroom, consider using the excellent and motivating activity “In the Courtroom: Understanding the Players and the Action,” which presents a trial of Goldilocks (see Resources). In this activity, students learn the workings of the legal system by acting out a criminal trial and assuming different courtroom roles. The website offers suggested courtroom diagrams, litigation vocabulary, and a trial script of the story characters. This activity connects students’ prior knowledge (the story of “Goldilocks and the Three Bears”) to something less familiar—using argumentation skills. It also serves as a means to enliven the introduction of argumentation to the science classroom.

**Misconceptions on trial**

After showing students what argumentation looks like in the legal system, teachers can begin thinking about what topics to use to teach scientific argumentation. A good place to start is with topics that address misconceptions within science. Begin with misconceptions that are basic and will not generate distracting student emotions. For example, a familiar science misconception is that the distance between the Earth and the Sun causes the change of seasons. In this case, one set of “attorneys” can argue that the distance between the Earth and the Sun causes the different seasons, while the other set of attorneys argues that the seasons are caused by the tilting of the Earth’s axis. Hearing both sides of this argument will enable students to see how empirical evidence helps to support a scientific concept. Once all testimony and arguments are concluded, the rest of the students, acting as the jury, will declare a verdict.

*Science Court* is a media resource for classroom use that examines common science misconceptions through argumentation. The animated cartoon series, which aired on television from 1997 to 2000, explores science questions from an argument-based perspective through a courtroom setting. Misconceptions on trial include timeless science concepts such as electricity, gravity, inertia, sound, and the water cycle. Today
teachers can use the *Science Court* DVDs and accompanying instructional materials as a way to assist their students in using argumentation to uncover science misconceptions (see Resources).

*MythBusters* is a current popular television series that offers yet another avenue for students to witness the application of the essential steps of argumentation to determine the veracity of common misconceptions, although not exclusively science misconceptions. In each episode, the series’ hosts design a way to address different claims, myths, and misconceptions that are common in everyday life (see Resources).

Once students have practiced arguing science misconceptions, teachers can introduce more complex, current, and controversial topics that interest students. When the intensity of the discourse is scaffolded for students, they gradually become more proficient in their use of argumentation, even when the misconceptions are more complicated. This allows students to extend their understandings and eventually benefit from devising their own scientific arguments regarding misconceptions and topics of their own choosing.

Sample concepts and misconceptions to debate in the classroom, from simple to more complex, include the following:

- Earth-centric (Ptolemy) versus Sun-centric (Copernicus) universe
- Pluto: Planet or dwarf planet?
- A meteorite hitting the Earth caused the extinction of the dinosaurs.
- Euglena: Plant or animal?
- All magnets are made of iron.
- Cell phones can cause brain cancer.
- Tanning beds can cause skin cancer.
- Efficient sources of energy—oil versus solar power
- Global warming or the cycle of nature
- The expanding Earth or plate tectonics
- To frack or not to frack
Learning science through argumentation

Once students have gained basic argumentation skills from their courtroom-like experiences, they are better prepared to move on to designing and carrying out their own investigations, and using data to formulate claims with supportive evidence. At this point, middle-level students can be further encouraged to determine whether the data they collect are biased or flawed in any way and to communicate an explanation or model from the claim and evidence.

There is no doubt that possessing effective communication skills will be an essential aspect of scientific literacy in the 21st century. Scientific argumentation provides students with the opportunity to practice many useful critical-thinking and communication skills as they seek to create defendable arguments about different “sides” of scientific misconceptions. Through case studies, debates, and courtroom simulations, students learn to think about global issues based on empirical evidence. Argumentation also helps students formulate their points of view and opinions into justifiable claims based on supporting evidence and scientific reasoning. Students consider alternative viewpoints based on new evidence presented and foster respect for others’ points of view. In addition, argument-based lessons help students to make choices based on empirical evidence (rather than individual opinions) and develop positive attributes such as self-efficacy and intellectual self-determination.

Carl Sagan, in The Demon-Haunted World, said, “Both skepticism and wonder are skills that need honing and practice. Their harmonious marriage within the mind of every schoolchild ought to be a principal goal of public education” (1996, p. 306). A smidgen of skepticism and the wonder of inquiry will go a long way in helping today’s middle-level students separate authentic science from pseudoscience. For teachers, the transformation to scientific argumentation involves shedding “old skins” and altering our understanding of the dimensions of scientific literacy. For students, it means learning the true meaning of science.

Resources

Further reading on scientific argumentation in middle-level grades

Classroom tools
MythBusters—http://dsc.discovery.com/tv-shows/mythbusters
Science Court—www.tomsnyder.com/products/product.asp?SKU=SCISCI

References

Douglas Llewellyn (dllewellyn@sjfc.edu) teaches science education courses and Amanda Adams (adams_fields@yahoo.com) recently completed her master’s degree in math/science/technology education, both at St. John Fisher College in Rochester, New York.
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- Members save with discounts on insurance, Learning Center products, books, digital content and conference registration.
- And stay informed with our publications; *NSTA Reports*, *NSTA Book Beat*, *SciLinks* web content and our E-newsletters.

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Helping Students Evaluate the Strength of Evidence in Scientific Arguments

Thinking About the Inferential Distance Between Evidence and Claims

by Lauren Brodsky, Andrew Falk, and Kevin Beals

“Look, the dragonfly nymph is attacking the water snail. He’s eating it!”

“Nah, he’s just hanging on so he can go for a ride. The snail is carrying him around ‘cause they’re friends.”
As the exchange on the opening page illustrates, students tend to have no problem using inference to make claims based on what they directly observe. On the contrary, they often have to be reminded to make careful observations and ground their inferences in those observations and other data. Thoughtful science teachers spend considerable time working with students to improve their data-collection and recording skills, and in maintaining a distinction between what is directly observable or measurable by scientists and what must be inferred. But the act of making inferences also deserves attention. It can be tricky to teach students how to evaluate the strength of particular empirical evidence in relation to the inferences that can be made from it. When evidence and inferences are being tossed around your classroom, how do you help students to become more aware and thoughtful about evaluating them in relation to each other—and be appropriately tentative and skeptical?

The national guidelines and standards for science education emphasize both the importance of students making inferences from evidence to construct arguments and of students critiquing the strength of others’ arguments based on evidence (Achieve Inc. 2013; NRC 1996; NRC 2012). How do we as teachers support our students in understanding the relationship between observed evidence and possible inferences? How do we help students to think about how to use investigation, critique, and inductive reasoning to make stronger inferences or to seek stronger evidence for those inferences? In our work as science curriculum developers with middle school students, we have begun to develop what we believe is a promising way of thinking about the relationship between what is observed and what is inferred, and how to become more certain about inferences and resulting arguments.

In this article, we share a description of this proposed way of thinking about observations and inferences, called inferential distance. First we describe the context in which we explored the ideas in informal ways with middle school students. Next we describe three dimensions of inferential distance that can be used to critique different kinds of evidence. For each dimension, we describe some specific examples of how we introduced and examined it with students. We end with some more general suggestions about how to integrate this way of thinking into science instruction through classroom activities with students.

The context: An after-school program

We explored and tested our ideas about evidence and inference working with students in an after-school science program in a local middle school. One of us (Beals) met with students after school twice a week for three months. He worked with students to investigate terrarium pond ecosystems that included crayfish, dragonfly nymphs, tubifex worms, mosquito larvae, gambusia fish, freshwater snails, and other organisms. Beals and the students constructed a collective food web that represented the transfer of energy between the organisms in the ecosystem.

A primary focus of the program was developing students’ knowledge and skills with scientific argumentation, and students were expected to support the connections they created on the food web with evidence. Students recognized that connections could be more or less strongly supported, and with Beals, they developed a color-coding system for representing how confident they were about a particular connection.

- Orange arrows were inferred relationships without direct evidence. For example, “I think tubifex worms eat water plants, because they are sometimes on them.”

- Green arrows were supported by at least one direct observation by a student or an adult in the room. Adding a green arrow also involved some verbal peer review. For example, “Are you sure you saw it eat it?” and “Did you see it going into its mouth?” If students were reasonably sure of their observation, they would add the green arrow to the web, and write their name alongside the arrow.

- Pink arrows represented connections based on secondary information taken from a variety of written sources, and included the name of the source along those arrows, as well.

We did not use the term inferential distance explicitly with students. Discussing their connections in terms of their level of certainty accomplished the same goals of pushing them to weigh and evaluate evidence, and the wording was more accessible.

Inferential distance: A definition

To make an inference in science is to draw a possible conclusion based on known empirical evidence or information. The inferential distance is the size of the
conceptual leap made in going from evidence to conclusion. The shorter the inferential distance, the closer the conclusions are to being a direct description of the evidence. Figure 1 shows a visual representation of the relationship among evidence, conclusion, and inferential distance. However, inferential distance is not unidimensional; it can vary in multiple ways, making particular evidence stronger or weaker in relation to other evidence. We will use similar diagrams to represent those individual dimensions of inferential distance.

**Dimension 1: Inferential distance based on a subset of a population or category**

In many scientific investigations, the end goal of an experiment or set of observations is to be able to draw a conclusion that can be generalized to all examples of a phenomenon. Scientists, and students conducting classroom experiments, look for patterns or rules that can be applied to all equivalent situations in the natural world. For example, when scientists study the effects of a drug on a group of patients in a clinical trial, they would like to draw conclusions not just about the people in that trial, but about the drug’s potential effects on all people. To make these generalizations requires the inference that whatever results are found (in the lab, with a set number of measurements, etc.) is also true of everything in that larger category.

Scientists seek to maximize sample sizes or replicate investigations to better support these generalizations.

Inferential distance in this case describes the size of the inference that is made in moving from the actual evidence to the conclusion about the larger group and is related to the number of trials or observations that are made. If an investigation is being done to find out what crayfish eat, the end goal is to be able to conclude that what was observed is indicative of what all crayfish eat. If only one crayfish is observed, this evidence is clearly not very strong. If half of all the crayfish in the world were observed, there would be much more confidence in inferring that the rest of the crayfish eat the same thing. This trend continues—as the number of observations increases, the inferential distance decreases until all crayfish have been observed and no inference needs to be made—the conclusion becomes a description of the evidence. It is seldom, if ever, feasible to make all possible observations, and evidence from a comparatively small subset can still be strong. Being aware of the inference that is made in shifting from the observed subset to the whole population can help students weigh the strength of evidence between two different subsets, or to describe what assumptions are being made and how a given set of evidence could be stronger. Figure 2 represents this dimension of inferential distance.

Beals encouraged students in the after-school program to take into account the number of observations when evaluating the level of certainty of arrows in the food web. Over time, if others made the same observation someone else had already represented with a green arrow, they added their names to the arrow. This created a visual representation of the varying levels of certainty that existed even for interactions that were directly observed. Only one student observed evidence of a dragonfly nymph eating mosquito larvae, so his was the only name along the green arrow between them. The arrow connecting tubifex worms and gambusia fish ultimately had seven names written along it, representing seven different corroborating observations, and a much higher level of certainty. Figure 3 represents the different degrees of inferential distance in this kind of example.
Dimension 2: Inferential distance based on a model of a phenomenon

Another type of inferential distance that is common both in science and in the science classroom comes with inferring that evidence from a model of a phenomenon is evidence about the phenomenon in the real world. The inference is that the model behaves like the phenomenon it represents for the features being studied. For example, when scientists were studying how particular patterns of wing motion enabled insects to stay airborne, they created large mechanical wing models that imitated those patterns and used those models to measure the forces on the wings (Dickinson, Lehmann, and Sane 1999). Their inference was that the mechanical wings, which had the same shape and moved in the same ways as insect wings, would experience the same forces and provide the same lift that allows insects to fly.

In creating a model, assumptions must be made about which features of the phenomenon are relevant, and how they can be re-created in ways that behave similarly. The more similar the model is to the phenomenon (the more comprehensive the features, the more similar the scale, the more matched the materials, etc.), the more likely it is that it will behave as the phenomenon would, and the smaller the inference that needs to be made. This can continue until at some point the model is identical to the phenomenon and no inference needs to be made. Figure 4 represents this dimension of inferential distance.

The terrarium in the after-school program was serving as a model of a pond ecosystem. Students were inferring that the organisms in the terrarium would behave in the same way as organisms in a pond. When students were trying to determine what the gambusia fish ate, they had to infer that what they observed in the terrarium is what they would observe in a pond—that the model behaved like the real-world phenomenon. Many assumptions went into the terrarium model that could affect the strength of their evidence about the prey of gambusia fish. Students had to assume, for example, that what gambusia ate in ponds was available to them in the terrarium. Given two terrariums, one that included a more complete set of organisms from the pond, would require fewer assumptions about what a gambusia fish would or would not eat. If students observed gambusia fish eating tubifex worms in this more complete terrarium, they could be more certain that they were observing what a gambusia would eat in a pond environment.

The inferential distance from this model to the conclusion about pond interactions would be smaller than if they were making inferences using a model with only a subset of species. Figure 5 represents the different degrees of inferential distance in this kind of example.
**Dimension 3: Inferential distance based on alternative explanations**

Finally, inferential distance exists whenever there is a conclusion that one thing caused or resulted from another, but the causal interaction was not actually observed. Without direct observation, alternative explanations can always exist. The inference is that, of all the possible explanations, the one proposed is actually the case. Scientists looking for evidence that liquid water could once have existed on the surface of Mars initially had to rely on low-resolution images of the surface. They saw channels that could have been evidence of past surface-water flow but also could have been caused by lava. Scientists inferred, but were not certain, that the channels on Mars were in fact from surface water and decided to continue studying those channels. As higher-resolution images of the surface were collected, the possibility that some of the channels were created by lava was ruled out, and the conclusion that the channels were created by surface-water flow became more certain (Sharp and Malin 1975). Evidence for a proposed explanation becomes stronger as there are fewer possible alternative explanations that could also account for it, until cause and effect are directly observed, and no inference needs to be made. Figure 6 represents this dimension of inferential distance.

In the after-school program, students were unable to directly observe a dragonfly nymph eating anything, so a student set up an investigation in a more controlled environment. He put a dragonfly nymph in a separate container and then added mosquito larvae, counting them as he added them. When he returned the next day, he noticed that almost all of the mosquito larvae were gone. This student inferred that the dragonfly nymph ate the mosquito larvae and was ready to add a green arrow to the food web. Other students challenged his investigation and pointed out that there were other possible explanations for how the larvae disappeared. One student noted that the top of the container was not completely sealed, and instead of being eaten by the dragonfly nymph, the larvae could have escaped. The student who created the investigation decided to put the dragonfly nymph and larvae together overnight again, but this time he made sure the top of the terrarium was sealed. When the larvae were gone again the next day, students decided that this was stronger evidence that the dragonfly nymph ate the larvae. Based on this new evidence, the student added a green arrow to the food web with his name alongside it. There were fewer possible alternative explanations and so the inferential distance was smaller. Figure 7 represents the different degrees of inferential distance in this kind of example.
How to use inferential distance in the classroom

Helping students to develop an understanding of inferential distance (even if it is an informal understanding) is a powerful way of supporting them in both evaluating and producing scientific reasoning and arguments. Thinking about inferential distance can help students to critique evidence and related conclusions in the investigations and science texts they encounter in their classroom learning, and in their lives outside of school. It can also help them to construct their own conclusions and qualify them as more or less tentative. In Figure 8, we describe a set of strategies that we have found to be useful with students in introducing them to inferential distance and engaging them in using it to evaluate scientific arguments.

Conclusion

Given that the Next Generation Science Standards and the National Science Education Standards expect students to construct their own explanations based on evidence and evaluate and critique their own and others’ arguments, it is important to provide explicit instruction and coaching about what makes evidence weaker or stronger and what makes conclusions more or less certain. Thinking about the inferential distance between evidence and conclusion is powerful because it provides a means for students to weigh different pieces of evidence and to evaluate the strength of evidence in relation to particular conclusions. In this way, it offers a concrete approach to being appropriately tentative in drawing conclusions and making claims and in evaluating and critiquing different arguments in science.

References


Resource

Aquatic habitats: Exploring desktop ponds (aquatic ecosystem activity)—http://lhsgems.org/GEMaquatic.html
## FIGURE 8

### Instructional activities for teaching inferential distance

<table>
<thead>
<tr>
<th>Activity</th>
<th>How we implemented the activity</th>
<th>Example for one dimension of inferential distance</th>
</tr>
</thead>
</table>
| **Card sorts**                | We provide students with a question, a possible conclusion, and a set of note cards, each with different evidence. Alternatively, we provide a question and a summary of particular evidence, and ask students to sort conclusions in order of least to most tentative. We then ask students to sort the cards in order of most to least certain in relation to the conclusion or evidence. | Dimension 3: Alternative explanations  
Question: “What are the predator/prey relationships on the African savannah?”  
Possible conclusion: “Cheetahs prey on wildebeest.”  
The set of cards showed pictures representing various kinds of possible evidence (picture of a cheetah's sharp teeth; cheetah running behind a wildebeest; cheetah pouncing on a wildebeest; and cheetah tearing at a wildebeest carcass). |
| **Critical questions**        | Once students have an initial understanding of inferential distance, we provide them with a set of critical questions (Nussbaum 2011) that they can learn to apply. Opportunities for critique include conclusions drawn in scientific writing, scientific work that is reported in the news, or peers’ lab reports. Students can also critique the inferential distance involved when using models to investigate phenomena that cannot be brought into the classroom. | Dimension 2: Model of a phenomenon  
We asked students to critique the ways in which conclusions drawn about a pond based on their aquariums might be more or less strong. Critical questions we provided were “How is the model similar to and different from the situation or process we are drawing conclusions about?” and “How certain do the similarities or differences make us about our conclusions?” Before taking individual responses, we had students hold up one to five fingers to indicate the level of similarity or certainty. |
| **Possible conclusions and new evidence** | Once students are more comfortable critiquing inferential distance, we ask them to examine evidence that they have gathered or drawn from provided data. From the evidence, they propose multiple conclusions that they consider more and less certain based on that evidence. Alternately, they can propose the conclusion they think is currently the best one, and rate it in terms of certainty. We then invite students to propose further investigations that could make the conclusions more certain. | Dimension 3: Alternative explanations  
When students shared their observations of their terrariums, we asked them to suggest several conclusions based on the data, some that they thought were more certain, and some that they thought were less certain, because other explanations were possible (e.g., the mosquito larvae were eaten, or they escaped).  
We then invited the group to propose investigations that would test or control for an alternative explanation (e.g., tightly sealing the lid). |
A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (NRC 2012) describes a vision of students developing an understanding of the practices of science and engineering to build and revise their understanding of how the natural world and designed systems work. This National Research Council report poses a question: What might scientific and engineering practices look like in a science classroom? Many science teachers have their students memorize the scientific method as described in the first chapter of a textbook. This approach persists in spite of long-standing and consistent statements about the fact that the actual practices of science and engineering are quite different.

Teaching the scientific method in an algorithmic manner takes away from the creativity and critical thinking necessary for true science instruction. However, some science teachers actively involve students in the practices of science and try to have students acquire knowledge, learn skills, and develop abilities that help them understand science and engineering and develop competencies that will be important in everyday living. For students in these science classrooms, the world is one of scientific questions and engineering problems. Further, once the questions and problems have proposed answers and solutions, peers have to be convinced of their adequacy and efficacy. This last component introduces the role of conversations, critical discourse, and argumentation.
Earlier articles introduced scientific and engineering practices and various strategies in science classrooms (Bybee 2011; Duschl 2012; Sneider 2012; Krajcik and Merritt 2012; Reiser, Berland, and Kenyon 2012). In this article, we provide science teachers with a discussion that clarifies and justifies critical discourse and suggestions for promoting critical discourse and argumentation in science classrooms.

To most effectively engage students in the practices of science and engineering, one must provide opportunities for conversation (dynamic exchange of ideas and reflection), critical discourse (accentuating connections between ideas and evidence), and argumentation (use of evidence to process and learn about ideas) in the classroom. These are primary tools for communication and making ideas public in science and engineering. Through sharing ideas in the classroom, students make and defend statements about their understandings and are provided occasions for examining their own thinking and sense making (NRC 2005). As students make their ideas public, teachers can evaluate understanding by monitoring how students use evidence to support a claim. Argumentation (different from a polemic in nonscientific contexts) promotes as much understanding of a situation as possible and persuades peers of the validity of a specific idea (NRC 2008). As students learn to argue, they apply their emerging scientific knowledge in an attempt to justify claims and identify shortcomings in others’ arguments. Critical discourse through acts of talk and argumentation in the classroom provide opportunities to enhance conceptual understanding and strengthen students’ scientific reasoning capabilities.

**Essential elements of argumentation: An example**

In this example, the science teacher sets the stage for students to develop knowledge of the relationship of heat energy to the perpetual motion of particles and changes of state. Prior to students observing similar-sized pieces of dry ice in two different but identical-sized beakers (one beaker containing hot water and the other cold water), the teacher establishes expectations. The teacher informs students of rules, including respecting all classmates and their ideas and listening to and thinking carefully about what others say. Then the teacher informs students that they will be responsible for describing and drawing in their science notebooks their observations of the dry ice in both beakers.

Within cooperative groups, students prepare an evidence-based explanation as to why the temperature of the water in the beakers affected the sublimation rate of dry ice (instruction on the concept of sublimation occurred earlier in the unit). Bybee (2010) asserts that communicating scientific explanations and defending a scientific argument are instructional strategies that enhance students’ development of 21st-century workforce skills. After students develop explanations within their groups, the entire class is seated in a large circle with students facing each other to promote a natural flow to the conversation. Students share the explanations they developed with their small groups. This configuration promotes student-to-
student interaction rather than a question-and-response exchange with the teacher. The teacher addresses naive conceptions by distinguishing between steam and fog and informing students that the fog they observed emanating from both beakers was caused by CO₂ gas emitted from the dry ice encountering air and the water vapor in the air condensing into fog. Students explicate their reasoning by providing evidence in the form of quantitative data, which was recorded on a stopwatch within separate groups while the dry ice sublimated in each beaker.

**Promoting critical discourse and argumentation**

The following are essential elements to fostering critical discourse in science classrooms.

1. **Establish norms for discourse.** Norms include respecting others’ ideas, listening to others, maintaining focus on the concept, and practicing mutual accountability (Worth et al. 2009). Students must be comfortable sharing their observations, challenging the claims of their classmates, and taking risks to share their ideas. Explicit instruction and modeling about rules and classroom behavior will enhance the quality of the discourse. It is recommended that students be informed that they are challenging the presenters’ claims and not the presenter.

2. **Have a learning outcome.** Just as scientists and engineers use laboratory notes to prepare documents for public presentation to the larger scientific community, students need an avenue to communicate their gathered information. This avenue may take the form of using scientific evidence to develop a written explanation to support or refute a stated hypothesis or arrive at a group consensus as a result of contributions of others’ ideas. This element marks the shift from divergent to convergent thinking and reasoning as students focus on sharing their findings (NRC 2005). Progress in science is supported by a community and culture in which one’s work and reasoning are continually critiqued.

3. **Provide two opposing evidenced-based explanations or solutions.** Allow students to select the best explanation (science) or best solution (engineering) and state why they believe it is best. Situations with differing points of view reinforce the value placed in science on examining alternative ideas and thinking about one’s ideas (Keeley 2008). This cognitive dissonance also can lead to students explaining what they have learned and how their ideas have changed as a result of engaging in critical discourse.

4. **Emphasize student observation and inference.** Opportunities to explain, critique, and justify their observations allow students to engage in the practices of science and engineering rather than just being told about them. Emphasizing these skills serves as rudimentary scaffolding for making claims and supporting them with evidence during argumentation (Llewellyn and Rajesh 2011). Prompting students to evaluate a claim or convince others of its validity provides learners with an important learning opportunity.

5. **Address naive conceptions.** Oftentimes, learners’ ideas are prescientific and have limited usefulness because they do not hold accepted scientific explanations. Addressing naive conceptions will increase the likelihood of students gaining a secure understanding of scientific concepts. Beliefs are transformed not solely by confirming evidence but also by negotiating alternative hypotheses (Khine 2012). Knowing why the wrong answer is wrong is just as important as knowing why the right answer is right.

6. **Use prior knowledge to generate data.** Emphasize that the practices of science and engineering are ways to investigate and explain the natural world. Students can come to believe science is a compilation of truths to be memorized if we do not make it clear that science fundamentally depends on evidence that can be logically and independently verified (Alberts 2009). Providing data that show an interesting pattern in need of an explanation is also a tangible way to incorporate the practices of mathematics into our instruction.
Valuing critical discourse, recognizing cultural diversity, and promoting equity

Students in our science classrooms today come from a variety of cultural backgrounds and have many different ways of thinking about and interpreting the world. Additionally, some of our students may have discourse experiences that differ from their teachers’. (Let us be mindful, however, that there are no native speakers of science.) Emerging literature indicates that when provided with equitable science learning opportunities, students of color, students from low-income families, and English language learners (and other non-mainstream students) demonstrate higher levels of science achievement and develop into successful learners while maintaining cultural identities (Lee 2011). If science teachers focus on deficits in student language, it may become an impediment toward building on the strengths students bring to classrooms and creating conditions conducive to critical discourse and argumentation.

Providing equitable learning opportunities for critical discourse and argumentation involves valuing and respecting students’ prior knowledge and the experiences they bring to the classroom from their home and community. A key element to fostering robust student verbal interactions is valuing the diverse social and linguistic traditions of our students. When nonmainstream students enter into the practices of science and engineering, they do not leave their cultural beliefs and practices at the classroom door. A classroom environment that provides students from diverse backgrounds with opportunities to engage in the practice of scientific argumentation can actually serve as a productive entry point for students from diverse communities (NRC 2012). By engaging them in science and engineering practice of argumentation centered on evidence, we provide nonmainstream students with rich language opportunities and model what scientists and engineers do in the scientific community. In addition, such experiences provide opportunities for students to develop learning outcomes of language-arts standards. Instruction that engages nonmainstream

### FIGURE 1

The practice of scientific argumentation

<table>
<thead>
<tr>
<th>Engaging in argument</th>
<th>Engaging students in argument from evidence at the elementary school level includes the following:</th>
<th>Engaging students in argument from evidence at the middle school level includes the following:</th>
<th>Engaging students in argument from evidence at the high school level includes the following:</th>
</tr>
</thead>
</table>
| The practice of argumentation focuses on sharing and interpreting ideas and observations. Engaging in argumentation means comparing and differentiating between these ideas and observations to build scientific knowledge. This scientific and engineering practice makes student thinking visible through the use of evidence and reason to develop an explanation. | • Distinguishing evidence from opinion  
• Listening to others’ arguments and asking questions to clarify their reasoning  
• Constructing an argument for one’s own interpretation of natural phenomena and collecting data | • Identifying which aspects of evidence support or refute an argument  
• Critiquing by asking questions about one’s own findings and those of others  
• Identifying weaknesses in data or a claim and then explaining why their criteria in support of a claim are justified | • Distinguishing among a claim, warrants, qualifiers, and data  
• Identifying the flaws in one’s own argument and modifying and improving them in response to criticism  
• Constructing an evidence-based model to refute the validity of a competing argument |
students in this approach is more likely to help them view themselves as successful science learners and become members of a science learning community while remaining members of their own community.

Application in a science classroom

The last academic year (2011–12) found one author (Huff) participating in frequent parent-teacher conferences and meetings with colleagues within his district because of the diverse learning needs of the nonmainstream students in his science classes. One particular student had a learning disability and moderate to severe bilateral hearing loss; an assistive listening and technology device was used in the classroom so the student could hear the instruction. This student was an English language learner who entered the district from Ethiopia two years ago. The parent-teacher conferences regarding this student were very meaningful because they provided insights into her communication patterns and how she worked to overcome her hearing loss while developing her English language proficiency. Her education needs in the classroom were addressed through additional consultation with the district teacher for the deaf and the English-as-a-second-language teacher regarding program accommodations from her individualized education program. This accommodation was implemented in a small-group setting and promoted risk taking while nurturing an increased sense of confidence as she shared her thinking. Additional classroom accommodations implemented to meet her vocabulary and pronunciation needs included limiting linguistic demands by having her draw and label diagrams and pictures of content and asking her to orally explain her thinking through these drawings and observations. This strategy was also an effective learning strategy for mainstream students because it allowed me (Huff) to begin implementing an evidence-based explanation framework where students make a claim, provide evidence to support the claim, and provide reasoning that articulates why evidence supports the claim (NRC 2007). Moreover, this approach was successful with mainstream students because it enabled me (Huff) to scaffold students’ observations toward more sophisticated explanations while providing equitable opportunities for all students to become increasingly confident and competent in talking about their thinking. Figure 1 contains a progression of argumentation. Assessing nonmainstream students’ level of engagement in the practice of scientific argumentation took different forms. Exit tickets and timing student responses served as efficient formative assessments. More complex methods of assessment involved taping student conversations to analyze how students made connections to ideas and how ideas evolved through the influence of instruction.

The importance of critical discourse in science classrooms

Argumentation is a central activity of scientists; however, collaborative discourse in today’s science classroom is virtually absent during instruction. The absence of argument is a product of the overemphasis of teachers, curricula, and textbooks on acquired knowledge at the expense of how we know (Osborne 2010). This overemphasis on knowing content at the expense of engaging in the practices of science often has a pejorative effect, because it leaves students with the idea that science consists of solved problems and theories to be transmitted. Osborne goes on to state that “deep within our cultural fabric, education is still seen simplistically as a process of transmission where knowledge is presented as a set of unequivocal and uncontested facts transferred from expert to novice.” Much of the talk in today’s science classrooms funnels through the teacher in what can be described as an initiate-response-evaluate approach to instruction. In this instructional strategy, the teacher asks a question, prompts a student for a response, and then follows with a comment that evaluates the student’s response. This instructional format emphasizes content knowledge, because the student supplies the teacher with a conclusion—an expected fact or information, not a claim supported by evidence or a comparison and contrast that distinguishes different viewpoints.

For students to engage in the practice of scientific argumentation, they must go beyond just giving a correct answer that centers on a scientific idea. Engaging in true scientific argumentation requires students to justify an idea and apply evidence and logical reasoning to support their viewpoints. Developing an understanding of science and appropriating the syntactic, semantic, and pragmatic components of its language requires students to engage in practicing and using discourse (NRC 2007). Although society
has come to recognize the countless benefits derived from science, there is less appreciation for the ability to use evidence in developing explanations, which causes students to represent information clearly and convincingly.

**Conclusion**

Manipulating knowledge through critical discourse and argumentation rather than just assimilating it allows students to process their ideas and observations. Embracing this science and engineering practice also provides a meaningful way for students to reflect on what they know and what ideas need to be refined to become consistent with scientific conceptions. Effective science instruction considers students’ prior knowledge, experiences, and beliefs in order to provide an equitable science experience for all students.

Argumentation is a hallmark of the practicing scientist and engineer and is essential to justifying one’s explanation. Successful science education is about students engaging in the practices of science and eschewing the monolith of textbook material to be memorized and recalled. It fosters scientific habits of mind emphasizing logic and data while being skeptical of claims absent of this evidence. Critical discourse and argumentation improve the quality of the learning experience, promote reason and critical thinking, and provide students with the capacity to use persuasive language to develop their scientific knowledge.

**References**


*Kenneth L. Huff* (khuff@williamsvillek12.org) is a science teacher at Mill Middle School in Williamsville, New York, and member of the Next Generation Science Standards (NGSS) Writing Team. *Rodger W. Bybee* (rodgerwbybee@gmail.com) is past executive director of the Biological Sciences Curriculum Study and member of the NGSS Writing Team, co-leader for life sciences.
While energy and forces must be taught in the middle school science classroom (NRC 1996), they are abstract concepts that students often have difficulty understanding. In this lesson, students work in groups of three to observe how varying the potential or kinetic energy on an object affects the force the object is capable of exerting on another. By recording their observations relating to energy and force, students develop a conceptual understanding of how the two are interrelated.
Crushing cans to explore energy

Before this one- to two-day lesson, students should have an understanding of force and motion concepts, specifically that force due to gravity on an object is dependent upon the object's mass.

To begin the lesson, engage the class by saying, "We hear or use the word energy a lot. What are some ways the word energy is used? What is the word describing?" After they have engaged in a think-pair-share, record on the board the ideas that students share, which might include thoughts similar to the following:

- "Sometimes I don’t have enough energy to do my homework."
- "Energy drinks help people stay awake."
- "My dog has a lot of energy; he never seems to stop running around the yard!"

While the word energy describes a plethora of things, your students likely have some misunderstandings of the concept, for example that energy is created and can be destroyed, or that objects at rest have no energy (Renner et al. 1990; Solomon 1985).

Next, show students the soda-can-crushing device (Figure 1), which consists of a ladder from which a weight will be dropped at different heights onto a soda can (see Figure 2 for instructions for constructing a device), and inform them they will be exploring energy by using the device to crush cans. Explain that they will use the can-crushing apparatus to explore how changing the energy of an object (the weight) affects the force the object is capable of exerting on a second object (the soda can). Ideally, students work in groups of three. If there is only one setup, student groups will need to take turns using the can-crushing apparatus. Each group will need at least nine empty soda cans.

Demonstrate to students how to safely use the setup by showing them how to properly pull the weight with the string and the pulley and place the can in position, however, do not spoil the excitement by crushing a can. Explain to students that they will be pulling the weight to different heights and crushing cans from these varying heights. Ask them to predict as a group how releasing the weight from varying heights will affect how much the can gets crushed, if at all. Have groups consider the science behind their predictions. In addition, pose these questions for groups to consider:

- What data must be collected?
- How will data be collected?
- How can you ensure the data are reliable?
- What are the variables?

While in their groups, students write their prediction, the reasoning for their prediction, and a detailed procedure for determining the effect of release height on the amount cans are crushed (length of
Crushing Soda Cans

**FIGURE 2** Constructing a soda-can-crushing setup

**Materials (per setup)**
- 1.5 to 1.8 m (5 to 6 ft.) ladder
- 0.61 m piece of 2” × 4” lumber
- Pulley
- Weight
- Screw eye
- 1.5 to 1.8 m (5 to 6 ft.) of weed trimmer line

Your school may be able to provide you with these materials, but they can also be purchased from a hardware store. Finding a weight with a uniform surface area for crushing cans that can be attached to the ladder can be difficult. I used a 25.4 cm × 25.4 cm (10” × 10”) steel plate intended for contouring soil when landscaping. The plate originally had a wooden pole extending from its center, which I cut off flush with the plate. I then screwed the screw eye into the wood plug that remained in the center of the plate. This plate was ideal because it had a flat surface, and its mass was relatively consistent across the entire surface area. This was the most expensive part of the setup, costing approximately $25. Another possible idea is to drop an 11 kg (25 lb.) metal plate (the kind use in a weight room) onto the can; however, getting the plate to land evenly across the top of the can and measuring the distance from which it is dropped would more challenging and less precise. Additionally, safety would be a concern because the weight would be dropped close to the releaser’s toes. The advantage of having the pulley is that students can release the weight while standing farther away from the apparatus and the weight can be held extremely still to ensure an accurate measurement.

**Procedure**

Nail the pulley to the 2 × 4, place the 2 × 4 between the fourth ladder rungs, and run the string through the pulley. Tie approximately 1.8 m (6 ft.) of weed trimmer line to the screw eye on the weight, which will allow for a clean release of the weight. (Weed eater string is better than rope because it does not stretch or break.)

Safety concerns include making sure the screw eye and string are securely attached; if the weight falls and lands on a finger or toe, this could cause bruising. Students and the teacher should wear safety glasses and students should stand a safe distance away from the apparatus. The teacher should supervise closely.

**FIGURE 3** Three soda cans crushed by weights released from increasing heights

The can on the left was crushed when the weight was released from a height of one half of a rung (approximately 15 cm [6 in.]), the middle can was crushed when the weight was released from a height of one rung (approximately 0.3 m [1 ft.]), and the can on the right was crushed when the weight was released from a height of two rungs (approximately 0.6 m [2 ft.]).
an uncrushed can, length of the crushed can), and draw a data table showing how data will be recorded. Students need to identify the independent variable, dependent variable, and any variables held constant. Ask students to consider how they plan to limit error in their experiment and check the procedure each group devises before allowing the group to start the experiment, ensuring the group identified the variables and created a data table to record information.

When checking students’ procedures, make sure they plan on measuring both the independent and dependent variables (both distances) using a tape measure. To limit error, students should perform replicates at each height and calculate the mean crush distance for at least three cans (Figure 3 shows three soda cans crushed by weights released from increasing distances). Students need to collect and record data, draw a graphic representation of the relationship between the release height of the weight and how much the soda cans were crushed (a line graph with release height on the x-axis and amount can was crushed on the y-axis), and provide a conclusion of their investigation in their journal.

Ask students to consider the data they collected. How did increasing the distance of the weight change how much a soda can was crushed? The evidence is straightforward. Students observed (as many had expected) that the soda cans would be more crushed with increasing distance. The next question is “Why, despite the force of gravity acting equally on the weight in all trials, did the cans get more crushed when releasing the weight from a greater distance?” Have students respond independently by writing in their journal. Students should be able to address this question, having previously been introduced to force and motion, and correctly explain the following: (1) The greater the distance, the more crushed the cans become; (2) the weight hits the can harder when it is released from a higher position; or (3) the weight has more energy when it hits the can when it is released from a higher point.

In-depth explanation
The weight released from the highest point started with a larger amount of potential energy. More potential energy was converted to kinetic energy. Kinetic energy is energy in motion and is dependent upon the object’s velocity. Therefore, when the weight was dropped from the highest point, when it hit the can, it hit at a greater velocity. How much the soda can was crushed from one trial to the next was dependent on the velocity the weight was traveling upon impact. The can was crushed more from the weight released from the taller height, not as a result of a greater force on the weight by gravity; rather, it resulted from the greater impact force of the weight on the can due to the greater velocity of the weight. Effectively, students witnessed and conceptualized the concepts of acceleration, velocity, and potential and kinetic energy. Taking the idea one step further, the teacher could explain that the amount the can was crushed was determined by the change in momentum in the weight over time.

Exemplifying transfer of energy
When an object is released, the potential energy is transferred to kinetic energy. The more potential energy there is to begin with, the more energy will be transferred to kinetic energy. The more energy an object has, the greater amount of work it is capable of doing. After students see that the weight falling from the second rung
did the most damage to the soda can, explain that the weight had more potential energy to start. The weight with the most potential energy eventually had the most kinetic energy after the string was released. Next, ask where the extra energy to really flatten the most flattened can came from. Students should be able to answer that the extra energy came from the individual’s muscles pulling the weight all the way up to the second rung, compared to the energy needed to pull it to the first rung. Through a short series of questions and answers, the teacher exemplifies how energy is transferred:

Teacher: “Where did the muscles get energy?”
Student: “From the food we eat.”
Teacher: “Where did that energy come from?”
Student: “Sunlight.”

**Extension**

The University of Colorado at Boulder has created an interactive simulation that can be downloaded for free (see Resources) and is a great way for students to elaborate on the energy concepts they’ve learned through the can-crushing activity. In this simulation, which is set at a skate park, students see how potential and kinetic energy are conserved in the system, as well as create their own skate park. The website also includes labs created by middle and high school teachers that correspond to the simulation.

**Evaluate**

This evaluation is a summative assessment of student learning and a bridge to the next investigation. Use an assessment probe and ask students to consider the following situation:

*Lewis, Tom, and Sophia have three different types of balls that are all different sizes. Ball 1 is a bowling ball and has a mass of 6,300 g. Ball 2 is a tennis ball and has a mass of 56.63 g. Ball 3 is a golf ball and has a mass of 45.9 g. Lewis, Tom, and Sophia hold their arms out the window and drop the balls from the third-story classroom at the exact same time.*

Students use a table (Figure 4) to predict the order in which the balls will hit the ground and indicate which ball has the most energy. In addition, to promote critical thinking, have students describe the “rule” they used to fill in the table and explain their thinking. What teachers will find is that most students think that the bowling ball will hit the ground first, then the tennis ball, and then the golf ball. They reason that falling

---

**FIGURE 4**

Student data table

Students fill out the table to predict which object has the most energy and will hit the ground first.

<table>
<thead>
<tr>
<th>Type of ball</th>
<th>Order in which the ball will hit the ground (e.g., first, second, third, same time)</th>
<th>Amount of energy of each ball (e.g., most, second-most, least, same)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tennis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golf</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Students witnessed and conceptualized the concepts of acceleration, velocity, and potential and kinetic energy.*
objects that have more mass have more energy and also travel at a greater velocity than objects with less mass. Students support their claim that falling objects that have more mass will have more energy based on the data they collected during the can-crushing lab.

To test the idea that objects with more mass fall at a greater velocity, students perform the investigation described in the assessment probe using the different-sized balls. Teachers need to make sure they let other teachers and school personnel know that different-sized balls will be dropped from a window. In addition, the demonstration works best if most students observe the demonstration from the ground at a safe distance (25 m). Alternately, teachers can easily videotape the demonstration for students to watch and analyze.

Students are shocked to learn that the balls hit the ground at the same time. Teachers can reinforce students’ experiences in the can-crushing lab by having them observe the indentions left in the ground by the different-sized balls. Students will see that the bowling ball leaves a bigger indentation in the ground than either the tennis ball or golf ball. The assessment probe followed by the investigation helps students develop greater understanding of the relationship among mass, energy, and velocity of different falling objects.

Conclusion
This lesson is an excellent way to get students thinking about acceleration, gravity, energy, and momentum without emphasizing which equation to use and for which problem or situation. Students must understand the concept and know what it looks like (meaning they must conceptualize the physical processes) before trying to put the random puzzle pieces together. All too often teachers hear, “I don’t know why I get the right answer doing it this way, but this is how you do it if you want to get this problem right.” The lack of conceptual understanding, despite coming up with the correct answer, is not what students need, but it seems too often that this is what happens. Instead, students need concrete experiences to help them develop fruitful understandings of science concepts (Posner et al. 1982).

This lesson helps establish conceptual understanding by emphasizing an inquiry approach, whereby students devise their own procedure and figure out what data they need to collect. This, in essence, emulates the process of doing science; likewise, this lesson emulates how scientists come to understand physical phenomena.

Standards
This lesson addresses the Standard MS-PS3 Energy from the Next Generation Science Standards (Achieve 2013). Specifically:

Science and Engineering Practices:
- Planning and carrying out investigations
- Developing and Using Models
- Constructing Explanations and Designing Solutions

Disciplinary Core Idea
- PS3.A. Definitions of Energy
- PS3.B. Conservation of Energy and Energy Transfer
- PS3.C. Relationship Between Energy and Forces

Cross Cutting Concepts
- Scale Proportion and Quantity
- Systems and System Models
- Energy and Matter

References


Resource

James Concannon (jim.concannon@westminster-mo.edu) is a professor in the Department of Education at Westminster College in Fulton, Missouri. Patrick Brown is a science teacher at DuBray Middle School in St. Charles, Missouri. Laura Stumpe is a professor of physics and Elise Bartley is a professor of business and accounting, both at Westminster College.
A Framework for K–12 Science Education (NRC 2012) identifies three dimensions of K–12 science and engineering curricula and classrooms are addressed in the Next Generation Science Standards: scientific and engineering practices, crosscutting concepts, and disciplinary core ideas. The concept of argumentation is emphasized in practice #7 of the Framework: Engaging students “in argumentation from evidence about an explanation supports students’ understanding of the reason and empirical evidence from that explanation” (NRC 2012, p. 44).

But have you wondered what argumentation practices look like in the classroom? Have you been searching for ways to help students understand and appreciate science core ideas through argumentation? This article introduces a negotiation cycle to help teachers incorporate argumentation into the science classroom. The negotiation cycle, which is modified from the Science Writing Heuristic approach (Hand et al. 2009), emphasizes using argument as a vehicle to learn about scientific core ideas and practices. It also connects to the Common Core language-arts standards (NGA and CCSSO 2010), because writing and reading pedagogies are embedded in the cycle.

Teachers can use multiple rounds of the cycle to deepen students’ understanding of science core ideas. The numbers of rounds of the negotiation cycle will depend on how students progress, the depth of learning that is required, and students’ ability to shift
A Negotiation Cycle to Promote Argumentation in Science Classrooms

Learning science by engaging in argument from evidence

Science is not about discovering or memorizing facts; rather it is about constructing and critiquing arguments and considering multiple explanations for phenomena (McNeill 2009). Scientists construct their arguments and share them publicly to gain critique. The public critiquing process helps scientists to evaluate weaknesses in their work so they can strengthen their argument (NRC 2012). However, argumentation has “too often been underemphasized in the context of science education” (NRC 2012, p. 44). In order to engage students in constructing and critiquing arguments like scientists, the nature of typical classroom activities and discourse patterns needs to change. In other words, teachers must do more than tell students about science content or provide recipes to conduct fun, hands-on activities (Zembal-Saul 2009). Teachers also need to create learning environments where students can negotiate core ideas with peers by using claims and evidence to develop their understanding about the natural world (Hand et al. 2009). This is the idea of the first and third dimensions of the new Framework, which emphasize learning a limited number of core ideas through argumentation practices.

To accomplish this, students should be provided with opportunities to develop a tentative argument to answer a research question by connecting empirical data to their knowledge framework. Students are then asked to present their argument to others and negotiate its weaknesses, including inconsistencies, insufficient evidence, and relationships of the argument to the question and core idea. Once their argument is negotiated, students evaluate and revise it to develop a better argument and understanding to answer the research question (Sampson, Grooms, and Walker 2011).

The negotiation cycle introduced here demonstrates how to incorporate those ideas emphasized by the Framework into science classrooms (Figure 1). The negotiation cycle comprises six phases, each of which has a unique purpose in engaging students in argumentation practice (Figure 2). Engaging students in argumentation practice is challenging and won’t happen overnight (Cavagnetto 2011). It usually takes more than five months to move students from focusing on memorizing facts to constructing and critiquing knowledge through arguments. When students engage in the negotiation cycle over time, they develop the skills to look for patterns of data in generating convincing evidence, use evidence to frame an argument and then persuade peers of the validity of their points, and identify flaws in their own arguments (Chen 2011).

The negotiation cycle

A multiple-day lesson that takes place over two weeks is described here to illustrate how this negotiation cycle works. This lesson was designed to help students understand how the respiratory system works with other systems. Students were introduced to one core idea (human body systems work together) with one question (how does our respiratory system work with other systems?) designed to show the function of respiration. To blend this core idea with argumentation practice, students were asked to build a model to demonstrate and explain how the respiratory system works (see Figure 3).

Phase I: Identifying a research question

In the initial phase, the class develops a research question to guide investigation. To generate the re-
A NEGOTIATION CYCLE TO PROMOTE ARGUMENTATION IN SCIENCE CLASSROOMS

FIGURE 2  Six phases of the negotiation cycle

<table>
<thead>
<tr>
<th>Phase</th>
<th>Task</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Identifying a research question</td>
<td>Elicit prior knowledge and gain understanding of the scientific context in which the research question is explored.</td>
</tr>
<tr>
<td>II</td>
<td>Investigating in small groups</td>
<td>Learn how to collect data from an investigation, generate evidence with an appropriate explanation supported by data, and craft an argument that can be shared with others.</td>
</tr>
<tr>
<td>III</td>
<td>Presenting group arguments</td>
<td>Share arguments to gain critique and understand the weakness of arguments. Know how to critique other groups’ arguments and give feedback.</td>
</tr>
<tr>
<td>IV</td>
<td>Comparing arguments to those found in books and online</td>
<td>Refine and improve on initial arguments through thinking about peers’ critique, and information from textbooks and the internet.</td>
</tr>
<tr>
<td>V</td>
<td>Presenting revised arguments and learning crosscutting concepts</td>
<td>Share the revised argument to gain critique. Learn crosscutting concepts to deepen understanding of a given core idea.</td>
</tr>
<tr>
<td>VI</td>
<td>Reflecting individually through writing</td>
<td>Reflect on what was learned, the challenges faced, and if arguments answered the research question.</td>
</tr>
</tbody>
</table>

FIGURE 3  Student handout for the respiratory system

Core idea: Human body systems work together.

Research question: How does our respiratory system work with other systems?

Goal: Your group must design a model that can represent our real respiratory system to answer the research question. To be successful, you will need to develop your group’s claim and evidence that answer the research question by using the model you build. You may use the following materials during your investigation: plastic bottles, straws, clay, rubber bands, balloons, tape, scissors, blades.

* The diagram to the right is an example of a model that students may be able to develop to represent the system (students can develop other models that represent the system, as well). We suggest that teachers not provide this model for students in the beginning of the lesson. However, teachers should guide students to think about models that can really represent our respiratory system so they can eventually use the model at right to explain how it works with other systems.
A Negotiation Cycle to Promote Argumentation in Science Classrooms

Phase I: Generating a Research Question

Search question, teachers can provide a physical model or pictures to elicit and pique students’ diverse thinking about the role of the respiratory system in the whole human body system (Figure 4). As a class, students brainstormed what they already knew about the respiratory system and the human body system in general. Students were familiar with the purpose of the respiratory system in the human body system but unaware of how our respiratory system works with other systems. Through the discussion, students came up with an agreed-upon investigation question: How does our respiratory system work with other systems? This initial phase takes approximately 20 minutes.

Phase II: Investigating in Small Groups

After the class generated the research question, students were divided into small groups of three or four. Each group was given a packet that included materials and a handout with the goal and research question for the investigation (see Figure 3). Students were asked to use the materials to build a model to simulate how the respiratory system works based on their prior knowledge. This phase provides students with the opportunity to think about how to use the simulation model as evidence to explain how the respiratory system works and to test their ideas through peers’ critique in a group. In science, evidence not only includes qualitative information (e.g., data, observations), it also uses explanatory information that is related to the drawing or model (Villanueva and Hand 2011). A framework consisting of a core idea, a question, a claim, and evidence (Figure 5) can be introduced in the beginning of phase II and used to guide student argumentation practice. Based on their models and the framework, the groups generated a tentative claim and supporting evidence in response to the research question. Figure 6 is an example of one group’s tentative claim and evidence.

This framework in Figure 5 is used to drive argumentation practice when students engage in small-group investigation. For example, students in this investigation were required to answer questions such as the following: What is my claim? How does my claim answer the question? What evidence do I have for my claim? (Cavagnetto 2011). If students had difficulty building an argument, we used sentence stems.
such as the following to provide guidance in the use of claim and evidence: “My claim is _____ because_____ [evidence].” Prior to students going public with their ideas, we asked penetrating questions (Bass, Contant, and Carin 2009) to help them self-critique their own models. This private negotiation encourages students to use their empirical knowledge while writing their evidence to support their claim. Teachers can move from group to group and monitor student progress by asking questions such as the following:

- Could you explain how your model works?
- Show me the evidence from your model that supports the claim.
- Could you explain why you connect straws to the balloon?
- What evidence did you use from your model to explain the relationship between the lungs and chest?

It is important for the teacher to challenge and clarify students’ thinking without providing the “right answer.” In this phase, students’ models typically do not match the scientific model. This is perfectly acceptable as long as the student model is reasonable and feasible based on their current evidence. There will be multiple opportunities for students to revise their scientifically incorrect thinking. This phase of the negotiation cycle takes one or two 50-minute class periods depending on students’ previous experiences with argumentation. Figure 7 shows an example of a student’s first sketch and model of the respiratory system.

**Phase III: Presenting group arguments**

This phase provides an environment in which students construct and critique their claim and evidence in a whole-class negotiation. Students should be prompted to focus on the negotiation about claims and evidence rather than making a personal attack. The following guidelines are particularly important in this phase. Developing these guidelines with the class will create a sense of ownership, and therefore students will be more inclined to abide by the rules. These guidelines emphasize what students need to do and how to negotiate.

**What do I do when I negotiate?**

- Make others’ arguments better: Focus on the idea/claim/evidence, not the person.
- Encourage other students: If someone is not talking or has not had an opportunity to talk, involve that person by asking questions.
- Provide evidence for what you say: When you make a claim, you must support it with evidence. Challenge others’ thinking by using evidence.
- Be respectful: Use an appropriate volume and tone; listen to other ideas and make connections.

**How do I negotiate?**

- Take a side: Agree with what someone says or disagree with what someone says and explain why you disagree.
A Negotiation Cycle to Promote Argumentation in Science Classrooms

- Use conversation to find the most accurate conclusion. Try to let others see why you are thinking accurately.

The teacher needs to encourage students to provide feedback to other groups’ arguments and identify the weakness of their own arguments through the public negotiation process. It is most important that students ascertain if their claims are supported by evidence and explain the real situation. For example, after student groups presented their model of the respiratory system (shown in Figure 7), their peers critiqued the model with comments and questions such as “We don’t have people blowing air down your windpipe,” or “How do the muscles and the bones help to get air in and out of your body?” Peers’ critiques helped student groups to understand the limitations of their model, and they used the feedback they received when reconstructing their model in phase IV. We suggest that teachers give students one 50-minute class period to complete this phase of the cycle.

**Phase IV: Comparing arguments to those found in books and online**

At this point, when students are well aware of the weaknesses of their models, they conduct research online and using nonfiction texts to gather more information to revise their model. For example, students quickly did a general search for the “respiratory system” and found there is a muscle below the lungs called the **diaphragm**. This new idea sparked a flurry of questions and additional searches. Students were encouraged to find multiple sources that all support the same idea. This process allows numerous opportunities to make additional connections through the text, diagrams, and their own models. After using these resources to find out what others had said about ideas similar to theirs, students decided whether they wanted to make changes to their models based on what they’d learned through their research.

Using reading strategies can also help students make meaning from text and compare their ideas with texts. Figure 8 provides some suggestions for students when comparing their models with experts’ models from books or the internet.

Because the muscular system (diaphragm) is the key point to make the respiratory system work, teachers can scaffold students to focus on the exploration of what the muscles are while students search for information from books or online. Students usually encounter difficulties in understanding how the diaphragm interacts with the respiratory system. The teacher may interject questions such as the following: “What gives lungs their movement?”; “What is the diaphragm and where is it located?”; and “Put your hands on your chest while you breathe. Can you feel how changing the size of your chest makes the air go in and out?” These questions should be pinpointed to the relationship between the diaphragm and the lungs. Teachers’ questioning can scaffold students’ thinking toward the core idea. The research activity should take approximately one 50-minute class period to complete.

After comparing their ideas with other sources, students were provided opportunities to revise their

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**FIGURE 8**

Recommendations for comparing models with experts’ work

<table>
<thead>
<tr>
<th>Recommended</th>
<th>Not recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Articulate similarities and differences with text/expert.</td>
<td>Simply restate information heard from peers or taken from experts or continually repeat your own ideas with no regard for new learning.</td>
</tr>
<tr>
<td>Make connection between text/expert and your own argument.</td>
<td>Rarely or never listen to other ideas and connections.</td>
</tr>
<tr>
<td>Construct an improved version of the argument.</td>
<td>Make comments that solely attack peer ideas or only focus on yourself.</td>
</tr>
</tbody>
</table>
first models. Initially, many of the groups neglected to mention the relationship between the respiratory and muscular systems. Even when groups mentioned the muscular system in the previous model, they usually had difficulty explicitly explaining how these two systems work together. As Figure 9 shows, this time, students considered how the diaphragm, rib cage, windpipe, and lungs work together based on their group discussion and evidence from the internet and books. Although this model (and others) was still not completely consistent with a current scientific model, it did have sophisticated features. Specifically, the diaphragm worked in unison with the lungs and rib cage. The revision activity should take approximately one 50-minute class period to complete.

**Phase V: Presenting revised arguments and learning crosscutting concepts**

After student groups finalized their respiratory models, they presented them to the rest of the class. The model shown in Figure 9 received many peer critiques, including the following: “The diaphragm doesn’t touch them. You can’t move your lungs” and “You do not explain how the diaphragm works with the lungs.” These critiques stimulated students to reflect on the relationship between the diaphragm and the lungs. We suggest that teachers give students 30 minutes to complete the whole-class negotiation.

After group presentations, students may perceive the limitation of their knowledge to build a model that explains the system. At this point, we employed activities to help students understand that air is matter and takes up space as well as the relationship between air pressure and the volume of air. See the online version of this article at www.nsta.org/middleschool for an activity that demonstrates the relationship between air pressure and the volume of air. In the activity, students observe what happens to a marshmallow in a sealed syringe when the plunger is pushed down and pulled out. Teachers can have students place one finger over the syringe to seal the opening and ask students to describe how it feels when the plunger is pushed down and pulled out.

This activity helped students understand the function of the diaphragm and how the diaphragm works with the respiratory system through the concept of the relationship between pressure and volume of air. The focus was to integrate into this unit students’ knowledge from physics about the balance of space and air pressure. This is the idea of the second dimension of the new Framework that emphasizes learning crosscutting concepts across science disciplines. The activity should take approximately one 50-minute class period to complete.

Throughout the unit, students continually explored additional evidence about how the respiratory works with other systems, which targeted the core idea. We suggest that teachers give students at least 30 minutes to reflect on and revise their group arguments after introducing the relationship between pressure and volume of air. As Figure 10 indicates, at the end of the unit, most students developed models more consistent
with the current scientific model of the respiratory system. At this point, if there are any remaining students who do not yet understand how to make their model consistent with the scientific model, teachers should engage in Just-in-Time instruction to help these students understand how the diaphragm brings air into the lungs. The sketch and model in Figure 10 show that the diaphragm doesn’t have to touch the lung, and the lung still moves.

**Phase VI: Reflective writing**

At the end of the unit, a summative writing activity helps students reflect on what they’ve learned, the challenges they’ve faced, and whether their arguments answered the research question. This is also a good time to discuss the various aspects of the nature of science, that scientists revise their argument based on evidence and negotiation, and that scientific knowledge is tentative and changes over time based on evidence. Each student was required to produce a written argument in support of one of the claims and evidence. This writing activity also provided teachers with a window into each student’s thinking, a summative assessment of student learning, and an opportunity to give students useful feedback.

Because writing a strong claim and evidence was difficult for students, we provided them with a guideline for doing so (Figure 11). See Figure 12 for a rubric for scoring these arguments; the rubric helped both students and teachers understand what counts as a good claim and what counts as good evidence. Teachers can tailor the rubric as needed to fit a specific unit or situation.

The following example, which clearly demonstrates knowledge of how the diaphragm works with the lungs and rib cage, is excerpted from one student’s work: “When the diaphragm goes down, the rib cage gives the lung more space. The diaphragm going down creates a larger space, or area of lower air pressure inside of the body than outside. The air of higher pressure travels to the area of lower air pressure until the pressures are equalized. When the diaphragm moves upward, the chest has a higher air pressure than outside and forces the air out of the body.” This phase of the lesson requires one 50-minute class period to complete.

**Benefits of the negotiation cycle**

This negotiation cycle can help students engage in argumentation practices blended with core ideas. It can also help students develop critical-thinking skills, conceptual understanding, and communication skills through talk and writing activities (Chen 2011). The negotiation cycle proposes a way for students to move away from being passive learners with didactic instruction to becoming independent learners who can take ownership of their learning and engage in argument from evidence (practice #7; NRC 2012). This negotiation cycle also aligns with recommendation 4 of the Framework: “Standards should emphasize all three dimensions articulated in the framework—not only crosscutting concepts and disciplinary core ideas but also scientific and engineering practices” (NRC 2012, p. 300).

Follow-up test results showed that the group of students that used the negotiation cycle to study science over time performed better on critical-thinking tests and the Iowa Test of Basic Skills than students who were taught using lecture-based teaching strategies (Akkus, Guel, and Hand 2007). For example, the effect-size calculations for critical-thinking tests indicated
## FIGURE 12
Rubric for the writing assignment

<table>
<thead>
<tr>
<th>Score 1</th>
<th>Score 2</th>
<th>Score 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Core idea</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Difficult to identify the main theme or concept: What is the writer's main point or purpose?</td>
<td>• Conceptual science knowledge and core ideas are evident and correct in much of the writing.</td>
<td>• Conceptual science knowledge and core ideas are evident and correct throughout the writing.</td>
</tr>
<tr>
<td>• Only addresses organs of respiratory system.</td>
<td>• Only addresses the function of respiratory system.</td>
<td>• Addresses the function of the respiratory system and how the respiratory system works with other systems (e.g., muscular system, skeletal system, circulatory system).</td>
</tr>
<tr>
<td>• Addresses the function of respiratory system, but the concepts are scientifically incorrect or confusing.</td>
<td>• Addresses the respiratory and other systems, but does not clearly describe the relationship between the respiratory system and other systems and how they work together.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Claim</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Makes a scientifically incorrect claim. Makes a weak connection between the claim and question.</td>
<td>• Makes a scientifically correct claim, and partially catches the essence of the investigation. Makes a moderate connection between the claim and question.</td>
<td>• Makes a scientifically correct claim and completely captures the essence of the investigation. Makes a strong and sophisticated connection between the claim and evidence.</td>
</tr>
<tr>
<td>• Only states what the respiratory system is.</td>
<td>• States what the respiratory system is and how it works.</td>
<td>• States what the respiratory system is and how it works with other systems.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Evidence</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Provides an inappropriate and inadequate explanation or just reports data as evidence. Makes a weak connection between the claim and evidence.</td>
<td>• Provides an appropriate and adequate explanation partially based on interpretation of investigation data. Makes a moderate connection between the claim and evidence.</td>
<td>• Provides an appropriate and adequate explanation completely based on an interpretation of the investigation data. Makes a strong and sophisticated connection between the claim and evidence.</td>
</tr>
<tr>
<td>• Lists the major organs of the respiratory system; nothing is said about the function of the respiratory system and how the respiratory system works with other systems.</td>
<td>• Explains the major function of the respiratory system (e.g., gas exchange) and how the diaphragm affects the lungs' movement.</td>
<td>• Explains the function of the respiratory system and how the diaphragm affects the lungs' movement (e.g., uses the concept of the balance of air pressure).</td>
</tr>
<tr>
<td></td>
<td>• Distinguishes between internal and external respiration.</td>
<td>• Explains how the respiratory system works and how it affects other systems.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Uses scientific vocabulary correctly (e.g., exhale, inhale).</td>
</tr>
</tbody>
</table>
that using the negotiation cycle resulted in a large effect when compared to the group using lecture-based teaching. In addition, this negotiation cycle not only works with a variety of scientific concepts and age groups with appropriate modifications, it also serves as a practical approach for teachers when incorporating the Framework’s emphasis on argumentation into their classrooms.

References

Ying-Chih Chen (chen2719@umn.edu) is a research associate at the STEM Education Center at the University of Minnesota in St. Paul, Minnesota. Joshua Steenhoek is a fifth-grade math and science teacher at Jefferson Intermediate School in Pella, Iowa.
On most days, Sally sits quietly in her seventh-grade science class, overwhelmed by the thought of raising her hand to participate in the discussion. Sally, who has Asperger’s syndrome, has never talked in front of a class. But today she confidently walks up to the front of the room and presents her argument about why the Brazilian government should not build the Belo Monte Dam. Sally, who represents an indigenous Brazilian tribe in this activity, justifies her argument with evidence, detailing how the dam would negatively affect the Kayapo people. She doesn’t miss a beat responding to questions from other students, who play other roles in the controversy.
Sally is prepared and has a purpose: to persuade other students that her claim is correct. Preparing for the debate, she collected evidence from readings and videos, and organized that evidence into an effective argument. Her teacher (Grymonpré) checked in informally to make sure her claim had appropriate justifications. Her hard work is evident when she presents. Sally offers up the following:

This will be a devastating blow for the 10,000 tribal Indians whose lives have changed little since the arrival of Europeans five centuries ago. We, the Kayapo people, live beside the river, and the dam will bring an end to our way of life. The effect will be catastrophic and push us deeper into poverty, just as it did for the 40,000 people displaced by the Tucurui Dam in the 1980s.

In her closing statement, Sally appeals to her classmates’ hearts: “This is the second time we’re fighting this battle. Yet you still ignore us like we’re helpless animals or something. Why can’t you respect us?” Her connection to the argument is so powerful that the class “ooohs” in unison.

Although we changed the student’s name and some details to protect her identity, this example is based on an actual science lesson from the second author’s (Grymonpré’s) classroom. We have worked together over the last four years to support students in this type of argumentation; the students’ arguments we present in this article occurred during the last two months of an academic year. These students attend an urban public school and have diverse backgrounds and abilities, which we supported with multiple means of engagement (e.g., everyday, scientific, and socio-scientific examples), representations (e.g., using graphic organizers, modeling, constructing their own arguments, and critiquing others’ arguments), and expressions (e.g., reading, writing, and talking) as well as individual check-ins and constant feedback. One element we have found to be very important is that teachers must be aware of their students’ progress toward constructing effective arguments. While Grymonpré did an excellent job of supporting his students, including Sally, in the development of their argumentation abilities, this is a skill that he developed over time and one that he continues to refine. Based on what we learned from this lesson, we worked together to develop a checklist that will help teachers to assess the quality of their students’ arguments (Figure 1). The checklist can also be given directly to students to emphasize what they should consider when constructing their arguments. In this way, more teachers will be able to support students like Grymonpré supported Sally.
What is an argument?

Scientists build knowledge through the debate of claims and the evidence that is used to support them. Following this pattern, theories are rebutted and revised when new ideas are proposed. Yet any teacher knows that students, too, can argue. The challenge is getting them to argue using the scientific norms of evidence and reasoning. This challenge is worth surmounting, because doing so provides opportunities for students to clarify and expand on their science ideas and makes visible their scientific thinking and reasoning.

To help students express their arguments, we use a framework that simplifies this complex prac-

Students presenting their initial argument during the debate.
Assessing students’ Arguments

This challenge is further compounded by the need to monitor students’ progress over time.

To help address this pedagogical challenge, we present a pathway of students’ abilities as they progress toward mastery of this scientific practice (see Figure 2). The pathway includes benchmarks, such as using appropriate justifications and providing rebuttals. Because the benchmarks are applicable to both forms of communication, the pathway can be used to compare the quality of students’ oral and written arguments and track their development over time. At the lower levels of the pathway, students fail to construct an argument because they either do not provide a claim or do not justify their claim. Within the intermediate levels, students justify their claim, but they include inappropriate justifications. Justifications are inappropriate if they are conceptually inaccurate or irrelevant to the claim or contradict the claim. In comparison, at the highest levels of understanding, students use only appropriate justifications. It is at these levels that students approach mastery of the practice.

Teachers need to quickly and accurately decide where their students’ arguments fall along the pathway. To aide this process, we present a checklist that tracks benchmarks as they are satisfied (see Figure 1). It can be used when grading written arguments as well as when listening to oral arguments during classroom discussions. The checklist can later be compared to the pathway to determine the quality of students’ arguments.

What makes some arguments more sophisticated than others?

Assessing the quality of arguments, either spoken or written, is not an easy task. For instance, there are often numerous aspects of students’ writing that could be addressed, but it is difficult to know which are the most important. The in-the-moment appraisal required of spoken arguments can be even more difficult, because teachers need to make a quick assessment by emphasizing the structure of an argument. Specifically, the framework breaks an argument into the components of the claim and its justifications (McNeill and Krajcik 2012). A claim is a statement that answers a question. Justifications are used to support the claim, and their quality is measured in terms of appropriateness and sufficiency. We emphasize two forms of justification: evidence and reasoning. Whereas evidence consists of empirical data that support the claim, reasoning uses scientific principles or ideas to explain how or why the evidence does so. A rebuttal critiques the justifications for an alternative explanation. Middle school students should be able to construct justified claims, both orally and in writing, as well as rebut justifications for counterarguments. However, the quality of students’ arguments may differ across these two forms of expression.
What follows are an example of a socio-scientific argument and a scientific argument. Both examples demonstrate how the checklist and pathway to mastery can help a teacher quickly and effectively assess the quality of socio-scientific and scientific arguments as well as both spoken and written arguments.

**Socio-scientific example: Belo Monte Dam**

**Unit summary**

We designed a unit to help students develop written and oral arguments about the construction of the Belo Monte Dam along the Xingu River, a tributary of the Amazon River, in Brazil (see Figure 3). While the dam’s builders promise that it will provide clean energy, it will also displace a disempowered people and cause ecological damage. The dam was officially granted a construction license in 2011, and construction has recently begun. However, many indigenous people and local communities are actively occupying the construction site, and there are also several ongoing legal challenges to prevent Belo Monte from diverting the Xingu River. Prior to this unit, Grymonpré’s class had studied the physics of how hydroelectric dams generate electricity, and students had raised and released wild Atlantic salmon, which are endangered in part because of dams on their native rivers. Students had enough background knowledge to become motivated about the issue. Middle school students generally become fired up when

---

**FIGURE 6 Transcript of the Kayapo-tribe group’s oral argument**

Macarius: We are the Kayapo tribe. We the Kayapo tribe oppose the building of the Belo Monte Dam.

Zander: People have tried to prevent the Belo Monte Dam from getting built. In 2001, six people died because they were anti-activists and people and they were risking their lives to protect their land and their people.

Mr. G: Why were they hurt?

Zander: Because they were, they were trying to prevent the dam from getting built, and if the dam is built it will take our food sources, our transportation [inaudible]. We cannot feed a 130-kilometer stretch of people without water, food, or transportation.

Sally: This will be a devastating blow for the 10,000 tribal Indians whose lives have changed little since the arrival of Europeans five centuries ago. We, the Kayapo people, live beside the river, and the dam will bring an end to our way of life. The effect will be catastrophic and push us deeper into poverty, just as it did the 40,000 people displaced by the Tucuruí Dam in the 1980s.

Ochen: There are approximately 100 dams being planned for the Amazon rain forest. We are not getting any proceeds from these dams. And when the Belo Monte Dam is built they are redirecting the river so that it [bypasses] the Kayapo tribe.

Mr. G: Can you say that one more time? Do you need to draw it out or something? What do you mean?

Ochen: [drawing] Say this is the river. And we live in the area. If the dam is being built, the people, they will move the river in this direction [indicating in his drawing that the river would be circumventing where the Kayapo currently live along the river].

Zander: They’d be taking all of our water.

Mr. G: Why do you guys need that water?

Sally: Fishing.

Zander: For fishing, transportation, and water.

Macarius: Basically for everything we need to survive. Um, we’ve been fighting the Belo Monte Dam for 20 years, but right now no one is listening to us. The Belo Monte Dam will flood 400 square kilometers of land from us. This is equal to 40,000 football fields. It’s way bigger than Cambridge, Massachusetts. Questions?
Assessing students’ Arguments

The class was divided into role-based teams: Hydrologists studied the best placement for a hydroelectric dam; the power company realized the need for more electricity; the Kayapo people lived near the proposed site; climate scientists studied the environmental impact of building a large dam; and ecologists studied the dam’s impact on the Amazon rain forest.

Using news articles and websites as sources, we created a reading for each group that reflected the biased perspective of the specific role group. Each group had exclusive access to the vital information for its role. Because the real-life scenario is so complicated, we felt that it would be overwhelming to provide students with all of the information from every group. For example, students in the Kayapo group had a clearer understanding of the impact of the dam on their way of life, limiting their access to food, water, and transportation. Other groups understood that while much of the river was being diverted, water would still flow through the Kayapo land.

In the week prior to the debate, students completed a structured note-taking worksheet in which they made a claim, listed evidence from the reading, and later explained why each piece of evidence supported the claim. Because of the socio-scientific context, students used a range of evidence (i.e., it included scientific, ethical, political, and moral influences) discussing fair outcomes, especially when given the opportunity to persuade others.

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to help them justify their arguments. In preparation for the debate, each group developed an argument based on its notes, predicted other groups’ arguments, and generated a rebuttal for those that would likely disagree. For the debate itself, each group made an opening statement in which the group presented its claim and justifications. Next, other groups asked the presenting group questions or challenged the presenters’ evidence. Finally, each group gave a closing statement. Following the debate, students individually wrote an argument representing their personal perspective. They used the research from their oral arguments and justifications presented by other groups. The environmental-justice issue, presented in this format, motivated students to prepare strong arguments as well as to engage in the material and in discussion with each other.

Assessing the quality of students’ arguments

To assess the quality of students’ spoken and written arguments, we used the checklist and pathway to mastery (Figures 1 and 2). For instance, in their oral argument, which is presented in Figure 4, the climate scientists describe the situation nicely. However, they never present a claim, and they actually summarize both points of view, in the very last sentence, without taking a stance. Because they did not present a claim, none of the descrip-

![Density lab data sheet](image-url)
Assessing students’ Arguments

Assessing students’ Arguments can count as justifications, as there was nothing to justify. These students, therefore, did not construct an argument. The lack of benchmarks met is reflected on the checklist (see Figure 5). In comparing the checklist to the pathway to mastery, we see that this argument corresponds to level 0. It should, however, be noted that our checklist was developed using the student arguments from this lesson. If it was available in the moment students were constructing their arguments, it would have helped both the teacher and students focus on ensuring that students stated their claim. In both previous and subsequent arguments, these students did provide a claim in both oral and written arguments, which suggests that they may have overlooked the persuasive purpose as opposed to not knowing how to construct a claim. Regardless, this non-argument can be compared to the quality of the Kayapo tribe’s oral argument (see Figure 6).

Using the checklist (see Figure 7), we note that these students provided a claim and limited their justifications to those that were solely appropriate. They, however, did not rebut the other perspectives; as such, their argument was at level 6 on the pathway to mastery.

Finally, we look at Akil’s written argument (see Figure 8). Akil argued that the Belo Monte Dam should not be built and provided both appropriate and inappropriate justifications. For instance, he inappropriate justified that “most of Antarctica will melt if methane is produced” and “it can also make people severely sick and they can die.” However, he provided a strong rebuttal by critiquing how the newly generated electricity would be distributed. The checklist (see Figure 9) summarizes the benchmarks that he satisfied, and when compared to the pathway to mastery, we see that his argument corresponds to level 5.

Scientific example: Density

Lesson summary

In comparison to the Belo Monte Dam unit, in which students used secondary data, in this lesson students collected their own data. Specifically, they measured the mass and volume of five different colored liquids as well as calculated the density of each (see Figure 10). Each student then wrote an argument answering the following question: In what order do you...
predict the liquids from the lab will form layers? Lastly, the class performed the investigation to verify whether students’ predictions were accurate.

**Assessing the quality of students’ arguments**

Again, we apply the checklist in conjunction with the pathway to mastery to measure the quality of students’ arguments. In looking at Jasmine’s written argument about density (see Figure 11), we see that she argued that the liquids would layer from bottom to top: purple, green, red, (yellow), and blue. While she forgot to mention yellow in her initial claim, she did clarify where it would fall within the order later in the argument. We also see that all of her justifications are accurate and appropriate, and that she has a sophisticated understanding of density for a seventh-grade student. Because she did not provide a rebuttal, her argument corresponds to a level 6. The checklist (see Figure 12) summarizes the benchmarks she satisfied.

**Conclusion**

While the Belo Monte Dam unit provided opportunities for students to consider multiple perspectives and engage in argumentation, argumentation lessons need not always be this complicated. Providing opportunities for argumentation can be as simple as having students construct arguments as they make sense of data they collect during investigations. It is, however, imperative that students recognize that they are supposed to convince their audience. Therefore, when providing instructions for argumentation lessons, it is important to set expectations for students to be persuasive by emphasizing support and defense (Reiser, Berland, and Kenyon 2012). For instance, in introducing the Belo Monte Dam debate to his students, Grymonpré said:

> All right, as you’re preparing this, figuring out what you’re going to say, what’s most important, you might think about which facts, now that we’ve heard all of the evidence, are most important. Think about which arguments you really want to drive home.

Routine engagement in argumentation can be further supported through classroom norms. Specifically, students should know that they are supposed to support their claims with justifications. This means applying the concepts and self-monitoring their quality, as opposed to merely reciting the terms and definitions. For instance, a student might say, “What is your evidence for that?” when he or she doesn’t trust a claim proposed by another student. A poster listing possible prompts is a great way to remind students of the questions they should consider. Likewise, consistent and effective feedback helps to not only maintain argumentation norms but also support the development of students’ argumentation skills. The pathway to mastery and corresponding checklist are tools that can be used to quickly assess the quality of students’ spoken and written arguments as well as provide a focus for feedback.

**References**


**Amanda M. Knight** (knightam@bc.edu) is a doctoral candidate in the Lynch School of Education at Boston College in Chestnut Hill, Massachusetts. **Kris Grymonpré** is a middle school science teacher at McCormack Middle School in the Boston Public Schools.
What do productive discussions in the middle school science classroom sound like? What is the role of the teacher in such discussions? What are students’ roles? In facilitating a myriad of professional learning experiences (e.g., job-embedded graduate courses, professional learning communities, coaching experiences), we have observed that novice and experienced teachers alike struggle with engaging students in classroom discussions that include scientific argumentation, that is, arguments focused on the validity of evidence-based scientific explanations of phenomena (NRC 2007; 2012). The goal of such arguments is not to prove a point or identify a winner or loser, but rather to identify the explanation of a phenomenon that is best supported by the evidence. Ideally, argumentation in science is about sharing, processing, and constructing knowledge, and any criticism should target ideas and evidence, not the individuals who share them.
In the current reform efforts in science education, constructing and critiquing arguments are considered core processes of science. Through engaging in such practices, students understand the process of argument necessary for advancing and defending a new idea or an explanation of a phenomenon and the norms for conducting such arguments (NRC 2012). Just like scientists, they argue for the explanation they have constructed and defend their interpretations guided by the data they have collected while critiquing and providing counterarguments to their peers. When this occurs, students’ science knowledge becomes more meaningful, and over time they develop a good understanding of how scientific knowledge is produced.

We have observed that without substantial, ongoing support of scientific argumentation in the classroom, teachers and students return to familiar modes of discourse, all too often resembling initiation-response-evaluation (IRE) talk. In IRE talk, teachers ask questions, students respond, and teachers then evaluate and give students feedback on their individual responses. When IRE is the dominant discussion mode, the interactions among students are limited, and students do not experience the process of argumentation necessary for advancing and defending an explanation of a phenomenon. In this article, we describe several strategies we have used to support teachers in engaging middle school students in scientific argumentation as called for in the Framework for K–12 Science Education (NRC 2012). These strategies help teachers develop a community of practice in their classrooms where scientific argumentation is the norm and students participate regularly in sharing and critiquing ideas and presenting counter-arguments to their peers. They can be used by individual science teachers, instructional coaches, science departments, or professional learning communities in schools focused on improving the nature and quality of discourse in science classrooms.

**Analyzing video clips**

One strategy we have used to help teachers learn how to engage students in scientific argumentation is viewing video clips of discussions in science classrooms (see Resources) to differentiate among different types of classroom discourse. In working with our teachers, we select two to three clips that contrast teachers leading a typical IRE discussion with teachers facilitating a discussion that includes scientific argumentation. We then ask teachers to observe the video clips and identify which strategy resulted in students arguing for the explanation they constructed, using evidence they collected, or considering how evidence supported the validity of their claims. We ask the teachers to examine the questions asked in the videos and identify similarities and differences between questions that simply prompt students to give a response and those that encourage students to use evidence in some fashion. Finally, we ask the teachers to brainstorm how they might shift the line of questioning in the IRE discussion toward scientific argumentation. Some examples of the questions they typically identify to promote students using evidence to support or critique their arguments and to present counterarguments are as follows:

- How do you know?
- What evidence supports your idea/explanation/argument?
- What have you observed that tells you that ______?
- What have you experienced that tells you that ______?
- What is the quality of the evidence for ______?
- Do you agree with this idea/explanation/argument? Why or why not?
- What are other possible explanations for what you observed/experienced?
- Which idea/argument/explanation is best supported by the evidence that we have?

Many times, teachers post these prompts in their classrooms to not only remind themselves to probe students’ responses but also to support students in their attempts to engage in scientific argumentation.

**Analyzing recordings**

Another strategy we have used to support teachers in engaging students in scientific argumentation is asking teachers to record one of their class discussions. The teachers provide a brief description of the context of their lesson and then share their recordings with two or three fellow science teachers, who analyze the teacher’s role in facilitating scientific argumentation. We ask the group mem-
bers to listen to each other’s recordings without commenting or making judgments. As they listen, teachers silently note the types of questions asked and how the teacher initiated the discussion, provided wait time after asking questions (wait time 1) or student responses (wait time 2), commented on student responses, echoed or restated student responses, asked students follow-up questions, and invited other students to ask questions or offer comments. In the follow-up discussion, the listening teachers point out two or three of the recorded teacher’s actions that led students to construct and critique scientific arguments. At the end of their discussion, teachers respond to the following prompts in their journals:

- Students constructed scientific arguments when I ______.
- Students critiqued scientific arguments when I ______.
- Other teachers effectively facilitated student engagement in constructing or critiquing scientific argumentation when they ______.
- Other teachers inhibited students in constructing and critiquing scientific argumentation when they ______.
- What changes in class procedures, student groupings, or seating arrangements will I need to make to facilitate argumentation among my students?
- Before our next meeting, I will try the following strategies for more effectively supporting my students in constructing and critiquing scientific arguments:

**Peer coaching**

We also recommend peer coaching as a means to help teachers engage their students in scientific argumentation (Knight 2007). Peer coaching has been shown to positively support the lasting transfer of professional learning to classroom practices (Showers 1984). In peer coaching, teachers identify an area of need, in this case, engaging students in scientific argumentation, and work with a colleague to address this need. The two teachers observe each other during class discussions and record teacher-student interactions and student-student interactions. After the observations, the teachers come together to share the data collected and discuss the nature of the interactions, including how students were encouraged to participate and the level of scientific argumentation that occurred during the discussions. They ask each other thoughtful questions (e.g., How well do you feel students were able to support their scientific arguments with evidence? What if you asked Sara to share why she thought that? What if you asked class members whether they agree with Julio’s idea?), offer positive comments, and provide feedback on how they might foster and better support all students as active participants in scientific argumentation. The teachers often locate and share outside resources to support scientific argumentation in the middle school classroom during these conversations (e.g., NSTA books and journal articles about argumentation in the middle school classroom and investigations and projects that involve students in collecting and using evidence).

In peer coaching, the teachers’ conversations are characterized by mutual trust, respect, and, most importantly, choice. Thus, the language used is supportive and collegial. The teachers choose to work together and choose how they try or modify teaching strategies for involving students in scientific argumentation. As with students, choice is an important factor in teacher learning.

**Building a community of practice**

The last strategy we have used to support teachers in engaging students in scientific argumentation is helping them build a community of practice in their classrooms. Although middle school students may enjoy arguing, they are likely to be inexperienced in providing evidence for their ideas and uncomfortable judging the quality of others’ ideas. Indeed, having their own ideas judged by their classmates may bring some young adolescents to tears and recriminations. However, it is important for students to recognize and understand that science-specific argumentation is about understanding phenomena and using evidence to persuade their peers of the validity of their arguments. Thus, the interaction is guided by shared norms of participation as they engage and interact within the community of practice. We encourage teachers to have conversations with their students, to model for them what it means to have a scientific argument, and to help students understand that practic-
ing scientists share and critique each other’s work in the scientific community.

The initial step in these conversations is to contrast scientific arguments and everyday arguments. In their conversations with students, teachers should point out how scientific arguments focus on the quality and quantity of evidence supporting scientists’ ideas. Outright personal attacks are considered unacceptable and are a rarity in the scientific community. Teachers can involve students in brief role plays to highlight the differences between engaging in personal attacks and scientific arguments (see examples in Figure 1).

Furthermore, when scientists present their ideas at conferences or send their papers to scientific journals to be published, they do not share their ideas to “beat” other scientists or win an award; they are simply advancing the understanding of the scientific community of a particular phenomenon or occurrence in the natural world. Sharing examples of how scientists participate in a community of practice can be helpful to students. Nonfiction trade books about scientists and their work, interviews with scientists (see Resources), and research reports (see Resources) can all provide insight into the norms of participation in the scientific community. In addition, teachers can access video clips of conference proceedings where scientists share their work and are engaged in conversations with their peers (see Resources).

The next step in building a community of practice is to work with students to generate scientific argumentation “safety” rules and to include examples for participating in scientific arguments, such as the following:

- **Share your ideas in a respectful way** (e.g., take turns talking and listening to each other’s ideas, don’t interrupt or speak over each other, no name-calling or put-downs).
- **Agree with ideas that have convincing evidence** (e.g., “I agree with Shane’s idea...[discuss evidence]”).
- **Feel free to disagree with ideas, but not people** (e.g., “I disagree with Sam’s idea because... [discuss evidence]”).
- **Explain “how I/we know”** (e.g., “I know because ...[discuss evidence]”).

As with all classroom rules, it is best to teach, model, and practice these when they are first introduced, and when problems arise to re-teach, model, and practice them again.

At first, some middle school students may need additional support to join the community of practice. To guide students’ participation, we have worked with teachers to identify scaffolding strategies. One common strategy is to provide students with an organizer (see Figure 2) to complete before asking them to share

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**FIGURE 1** Role plays

**Personal attack**
Note that Terry’s comments do not address Candace’s claim about density. Rather, he makes comments about her personal appearance. If you notice your students engaging in personal attacks, be quick in redirecting their conversation to focus on claims and evidence.

**Candace:** I think that the density of the ball is less than the density of water because I saw the ball float when I put it in water. I know that things that float have a density less than the density of water.

**Terry:** Well, you’re wrong. You obviously don’t know anything about density since your hair looks funny. And have you brushed your teeth today?

**Scientific argument**
Note Candace’s emphasis on evidence and her use of questions to continue the conversation with Michelle about the quality of the evidence used to justify her claim.

**Michelle:** I think the density of the ball is less than the density of water because the mass is less than the volume.

**Candace:** Well, I think that the density of the ball is less than the density of water because I saw the ball sink when I put it in the water. Things that float have a density less than the density of water. How did you measure the mass and the volume? How did you make sure your measurements are reliable?
their scientific arguments. In this organizer, students record their ideas, record evidence supporting their ideas, and use reasoning to explain why the evidence and other scientific knowledge they may have support their ideas.

**Conclusion**

We consider teachers the linchpin in any effort to reform science education, and therefore they must be adequately prepared to implement reform-based science teaching practices such as engaging students in scientific argumentation. When students learn science in ways that mirror how scientists do science, they are better able to understand how scientific knowledge develops and gain deeper understandings of core scientific concepts. Furthermore, the ability to make and evaluate claims based on evidence is not just important in science. According to the Common Core State Standards, students should be able to think critically about what they have read, including making evidence-based claims (NGAC and CCSSO 2010). By shifting their classroom discussions toward scientific argumentation, middle school science teachers can enhance their students’ ability to consider the strength of claims they encounter in any part of their lives so that students always say, “Show me the evidence!”

**References**


**Resources**

**Scientists participating in a community of practice**


EurekAlert (research reports)—www.eurekalert.org

The secret life of scientists and engineers (interviews with scientists)—www.pbs.org/wgbh/nova/secretlife

**Video clips of discussions in science classrooms**

Discussion that includes scientific argumentation: The continental puzzle—www.teachingchannel.org/videos/continental-drift-lesson-plan?id=1

IRE discussion: Time management in 7th grade science—www.teachingchannel.org/videos/classroom-time-management?id=1

**Jennifer C. Mesa** (jmesa@coe.ufl.edu) is the project associate of the National Science Foundation Math Science Partnership grant U-FUTuRES: University of Florida Unites Teachers to Reform Education in Science, in the College of Education at the University of Florida in Gainesville, Florida. **Rose M. Pringle** is the U-FUTuRES co-principal investigator and a science education associate professor in the College of Education at the University of Florida. **Lynda Hayes** is the U-FUTuRES principal investigator and the director of the PK, Yonge Developmental Research School at the University of Florida.
What’s the best way to start an argument? As teachers, we can imagine the benefits of engaging students in shared discourse about the meaning and results of data, but it’s a challenge to get them started. How do we convince our students to care enough to actually argue about science? This article shows how curiosity and disagreement about the germination and growth of a seed can be used to lead students to collaboratively build understandings about growth through cell division.

To begin a scientific argument, students need a topic, a good amount of data, a difference of interpretation of the data, and some language or discourse tools. What follows is a sequence of lessons I developed to help middle-grade students learn and argue about the core concept of how a plant root grows at the cellular level. These lessons support the scientific and engineering practice of engaging in argument from evidence as laid out in the Framework for K–12 Science Education (NRC 2012) and the core life-science concept that multicellular organisms grow when individual cells expand and then divide repeatedly. This core concept is to be central in disciplinary core idea 1 of the life sciences at the middle school level in the K–12 Framework and the Next Generation Science Standards (Bybee 2013, p. 14).

This sequence of lessons has three activities that are each done in groups consisting of three students each. The groups stay the same throughout the activities. The sequence begins with an initial engagement with corn-seed germination and plant growth that elicits students’ conceptions and differing ideas and launches their inquiry. This initial lesson takes three full class sessions and requires brief daily checks of plants over a period of approximately three weeks.

In the second activity, students collect data about the cellular nature of root growth using classroom microscopes and commercially prepared slides. Onion mitosis root tip slides can be purchased from online vendors (see Resources); the cost ranges from $3 to $6 for each of the 10 to 12 slides needed. The slides are stained and mounted, so they last through multiple class uses and several years. If microscopes are not available, the investigation can be done with
Let’s talk science: seeding argumentation about cells and growth

images found online (see Micropolitan Museum in Resources).

In the third part in the sequence, students construct their understandings and come to consensus about the best explanation for how plant roots grow at the cellular level. These second and third lessons take four or five class periods each during the fourth and fifth weeks of the sequence.

I have successfully used this sequence of lessons to move the class dynamics away from a direct-instruction format to more student-led discourse. These lessons work very well during the first month of school to develop a foundation of understanding about cells and begin the essential scientific practice of engaging in argument from evidence.

**Differing ideas: Seeding the argument**

To begin the first activity, all students are handed two kernels of unpopped popcorn as they enter the classroom. Students can see that the kernels come from a bag of ordinary grocery-store popcorn (approximate cost is $4 for six classes of 30 students each). The question “Is a seed alive?” is written prominently on the board or otherwise displayed at the front of the classroom. Students are directed to position themselves on a line drawn across the floor.

**FIGURE 1** Sample classroom line used to probe student ideas about seeds

Is a seed alive?

Yes, definitely ___________________________________________ No, definitely not

**FIGURE 2** A student displays his team’s seed-germination apparatus

**FIGURE 3** Role playing for group science talk

Directions: Use the phrases in Figure 4 to tell what you could say if . . .

- you see something you are unsure about but think it might be important.
- you don’t understand what somebody said.
- you don’t understand why somebody thinks a certain way.
- somebody in your group says, “I think some seeds are still dead.”
- you have an idea that might be evidence, but you aren’t very confident.
- somebody makes a suggestion that seems really bizarre to you.
- someone’s idea doesn’t make sense to you.
- you feel like someone has a good idea, but you don’t understand it.
- you want to disagree, but you want to be respectful.
of the classroom to indicate their level of agreement in response to the question. Figure 1 shows an example of how the line might look.

Student positions on the line typically indicate a diversity of thinking. I use their positions to form groups of students with differing ideas about seeds and what it means to be alive. This diversity of thinking is a good place from which to develop a classroom community that supports argumentation. More student-initiated science talk happens when students are connected with peers who have opposing perspectives (Clark and Sampson 2007).

Students then write about their thinking and reasoning for their responses on their Activity Worksheets and discuss with their peers. (See the Activity Worksheet on pages 53–55 for activity details and connections to the Common Core language-arts standards.) Student talk typically includes statements such as “Seeds are not alive because they don’t move. They don’t breathe. They can’t do anything.” There are also students who think that the seeds are alive because they can grow into plants or because they can reproduce. Some students believe the seeds are neutral or that they are not alive yet but will be if they sprout. Other students say that to have enough evidence to conclude that the seeds are alive, they would need the seeds to show a combination of features. At the conclusion of this first day, students individually reflect in their notebooks, offering justifications for their own ideas and comparisons of their ideas to those of their teammates. Many students revise their thinking and writing after talking with other students.

On the second day, I give a mini-lesson about scientific observations, measurements, and inferences. Then I challenge the groups to design an apparatus that will enable them to observe, measure, and make inferences about the seeds over the next three weeks. There are clear plastic cups, soil (use only store-bought soil for safety), paper towels, water, and rulers out for students to use in designing an apparatus they will use for their investigation (approximate cost of materials is $15). We have a brief discussion about how a scientist might design the apparatus differently from how a gardener or farmer might plant the seeds. Each group uses its six to eight seeds and two or three plastic cups to assemble the apparatus. Groups engineer the materials in a variety of ways so they can see and measure the seeds as they germinate and begin to grow (Figure 2). On day 3, each group also begins its investigation by designing a chart or note-taking format to record observations, measurements, and inferences over time.

Student groups observe and measure their seeds daily, and individual students write about their interpretations and inferences. This should only take a few minutes each class period; the remaining time could be used to keep pace with the rest of the curriculum. Students intuitively begin talking about what counts as evidence in their investigations, however they might need guidance in writing inferences based on facts and reasoned judgment as articulated in the Common Core language-arts standards. The popcorn seeds usually germinate in 5 to 10 days, although students see changes as

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**FIGURE 4** Phrases to scaffold argumentation

- What do you think this means?
- Why do you think that?
- Here’s another way to think about that…
- Why do you think that would count as evidence?
- What else could we measure or describe to make a claim about the seeds?
- Do you mean…?
- What else could have caused that?
- I’ve noticed that…
- Have you thought about…?
- I don’t understand what you’re saying; will you explain more?
- Why is that important?
- I don’t understand why you think that. Will you tell me your reasoning?
- How can we use that to make a case for our idea?
- How will we explain this?
- Good idea, but what about this?
- What other evidence could go with that?
- This is what I think…
- Sounds good, tell me more.
early as the first day, when the seed begins to swell or the seed coat breaks. This first day the seeds are planted, day 4 of part 1, is a good time to introduce the language scientists might use to talk with each other about investigations. See Figure 3 for a role-playing scenario and Figure 4 for phrases that can serve as scaffolds to help students take the lead in directing their discourse. These scaffolds can be placed in sturdy, clear, plastic picture frames to post with the groups at their workstations.

Some students suggest that the seed swelling could be used as evidence of life because the seeds have changed in size, or have “grown.” Others counterargue that this is not evidence of life, because nonliving things can swell up when filled with water. Teachers need to move among groups and take notice of and respond to what students are doing, what they are saying, and the evidence and reasoning they discuss. An essential first step in building a climate that will lead students to the scientific practice of

**FIGURE 5** Phrases for talking about cells

- Why do you think that? What is your reasoning?
- What is the evidence for that?
- Why do you think that counts as evidence?
- What claim can we make about how the root is growing?
- Do you agree? Do you disagree? Why?
- What is the pattern here?
- That’s only one piece of data; what about all the data together?
- What about these other cells?
- What is happening inside the cell?
- Why do you think that will support our claim?
- What exactly is our claim?
- What about this example?
- I agree because…
- I don’t agree because…
- Look at this cell. What’s happening in this cell? Why?
- How is that related to what is happening in the other cells?
- Do we have enough evidence to say that? What kind of evidence do we need?
- How can we explain this one over here?
- How often is that happening? Why?
- What reasons do you have for saying that?
- We don’t have to keep that claim. We could change our claim.
- If we change our claim to…
- This makes sense to me…
- This doesn’t make sense to me…
- How about this example? How does that support our claim?
- Here’s a different one. What can we say about it?
- I just thought of something about what we said earlier…
- Can we make that claim even with this…?
- Good idea, but what about this…?
- How can we change the claim so we use the data from more cells?
- What does that mean?
- This doesn’t make sense to me.
- I think we need to change our argument.
- I think this means that…
- These cells show that…
- How do these go together?
- Do you agree?
- Why do you think that makes sense?
- This doesn’t make sense to me…
- Here’s another way to think about it…
argumentation requires that teachers acknowledge and respond to student use of evidence and reasoning, however current studies report that this behavior is rare in American classrooms (Levin et al. 2012; Michaels, Shouse, and Schweingruber 2008).

Students are always excited when they see popcorn kernels germinate and grow into plants. They typically suggest that the seeds are alive because they grow, mature, and change over time. They make claims that the seeds are growing and use their measurements and observations to support these claims.

From interactions with their peers, many students change their thinking and writing about what it means to be alive. They realize that there’s a wide range of reasonable and acceptable answers to many scientific questions. They talk about what it means to be alive and disagree about whether or not they have enough evidence to claim that the seeds were alive before they germinated. Students often suggest that scientific explanations of growth can go deeper than the macroscopic measurements and observations they are collecting. When students see microscopes set up around the room, the group talk usually turns to the idea of looking at cells. They notice that the roots are growing fast and are excited at the prospect of being able to observe root cells under a microscope.

**The microscope investigation: Data and reasoning**

After the germination, students begin to talk about what might be happening at the cellular level that enables the seeds, particularly the roots, to grow. Students typically hypothesize that the individual cells are swelling and enlarging to make the organism grow, but many have the misconception that the cells themselves or the number of cells remains the same. Alternately, some students believe that the cells make more cells, but they don’t have a concept of where the cells get the information to do so. Students usually have misconceptions about the roles of the nucleus, chromosomes, DNA, and cell cycle. Many students imagine cells as little organisms in-
stantly stamping out duplicates, and they suggest that moving water or soil might be the driving force.

During the fourth week, students use compound microscopes to look at the commercially prepared slides of onion root tips. These slides have been stained to highlight the structures inside the cells as they undergo mitosis and cell division. Root tips are a good choice for this lesson because they contain cells that are growing and dividing rapidly. Students are able to clearly observe the chromosomes of the nuclei in various stages of mitosis and cell division at 250 or 400 times magnification. This collection of cells offers a jigsaw puzzle the groups can use to figure out what might be happening at the cellular level that leads to the rapid root growth they observed earlier.

Groups work together to observe, analyze, and make inferences about the data on the slides. Students are directed to sketch and label their observations,

<table>
<thead>
<tr>
<th>FIGURE 8 Rubric for engaging in argument from evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socially constructed meaning develops over time, and as such should be assessed by observations of students in collaborative contexts (both oral and written).</td>
</tr>
<tr>
<td><strong>Undeveloped (1 pt.)</strong></td>
</tr>
<tr>
<td><strong>Claim</strong></td>
</tr>
<tr>
<td>Claim is not clearly defined or remains vague.</td>
</tr>
<tr>
<td><strong>Evidence</strong></td>
</tr>
<tr>
<td>Evidence remains anecdotal or stays at the level of personal experience. Evidence over time remains irrelevant.</td>
</tr>
<tr>
<td><strong>Reasoning</strong></td>
</tr>
<tr>
<td>Focus remains on being right or wrong instead of the thinking and reasoning.</td>
</tr>
<tr>
<td><strong>Socially constructed meaning</strong></td>
</tr>
<tr>
<td>Group collaboration remains limited to dividing work, turn taking, or distributing tasks.</td>
</tr>
</tbody>
</table>

Ideas for this rubric were gleaned from Berland and McNeill (2010). The final rubric reflects the author’s own interpretation, which has been made applicable to these lessons.
count occurrences of variables they deem relevant, look for patterns, and collect evidence so they can make claims about what is happening at the cellular level that enables roots to grow. Teachers can lead students to role-play discourse situations using the phrases in Figure 5.

Listening to students talk during this activity is similar to listening to students putting together a jigsaw puzzle: Some suggest that they found cells that go together in a pattern, followed by a group conversation about how, why, and if the cells fit together or a student locating a newly found piece to fit into the puzzle. Groups that seem unsure about how to proceed are prompted to use the phrases and questions posted around the room (Figure 4). The prompts also help students reinterpret data or consider parts of the data that don’t fit with their original thinking. For example, students who find “evidence” confirming their original thinking about swelling of cells sometimes miss the clues inside the nuclei until other students point them out. Teachers should circulate among the groups to notice, acknowledge, and respond to student use of evidence and reasoning. The prompts in Figure 5 are useful both to teachers and to students.

The argument: Making and defending claims

Groups use the structural framework shown in Figure 6 to form a claim that they will later share with another group. This framework originated from the work of Toulmin (1958) and has been used in many science classrooms and current research (Berland and McNeill 2010; Clark and Sampson 2007; Michaels, Shouse, and Schweingruber 2008). The framework includes a claim, evidence, and reasoning (see Figure 6). As a group, students discuss and decide on the best claim to explain how the root grew based on the data analyzed. Some groups make bold claims and even suggest a sequence that the cells undertook. Other groups’ claims are more modest, such as that cells divide up the nucleus in order for an organism to grow or that roots grow when cells expand and then split into two more cells. Ask groups to revisit and revise their claims the next day and offer them enlarged photos of the microscopic slides that they can quickly reference (Figure 7).

At this point in the set of lessons, students have a topic, a good amount of analyzed data, a classroom community that focuses on thinking (and makes it ok to be wrong), some discourse tools, and a meaningful reason to engage in argumentation from evidence. Then I select groups with opposing ideas to meet with each other to present and defend their claims. Students are still new to this scientific practice, so the phrases to scaffold the discourse (Figure 5) remain posted around the room, and students are reminded to keep the experience respectful by sticking to the phrases and questions on the posters.

Many of the groups are shy about presenting their claims publically, and there can still be hesitation to disagree. There is usually talk that leads students to reconsider the meaning of data as evidence and to consider different perspectives. I ask students to take notice of and comment on the justifications and reasoning of their peers rather than the accuracy of their claims.

Assessment

It’s important that teachers use classroom observations and interpretations of student behaviors as formative assessments. When students are new to the practice of argumentation, there is often better evidence of learning in these observations than in a single example of student writing (Berland and
McNeill 2010). It’s also important to consider a collection of observations over time. Figure 8 offers a rubric for assessment appropriate for this sequence of lessons. When assessing students, keep in mind that they need time to reflect, discuss, disagree, re-check, and revisit data multiple times in different contexts to demonstrate the practice of argumentation from evidence. Students also need a climate where it is safe to be wrong and where the focus is on reasons for ideas rather than only on the accuracy of ideas. Teachers might also consider student sketches as evidence of learning (Figure 9).

**Conclusion**

Students emerge from these lessons with enthusiasm for doing real science, new skills in “talking” science, novice but authentic experiences in the practice of engaging in argument from evidence, and a good foundation for thinking at the cellular level. Throughout the rest of the school year, my students and I called on our collective memory of the onion root mitosis slides to remind ourselves about cells and chromosomes. When we began learning about genetics, and later evolution, it was easy for students to imagine these topics at the cellular level, and they themselves directed the conversation there. Additionally, students continued to use the talk stems and phrases in the posters to build on the argumentation skills they’d learned.

If there had been more time, I would have helped students build skills for reaching consensus and require that they prepare a formal public poster for a wider audience. In following lessons, it was useful to ask groups to imagine a situation where another team disagreed with them; they were able to role-play how they would respond.

I have used this sequence of lessons with classes that include English language learners, special education students, and advanced honors students. The quest to figure out how a seed grows into a seedling at the cellular level motivates diverse groups of students to look for patterns of evidence and to interact with peers to develop a coherent claim. We, as teachers, need to remember that students argue when they have a strong interest in a topic, when they are able to gain enough evidence to build a coherent claim, and when they have contributed to building a community that values thinking, reasoning, and genuine scientific pursuits.

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**References**


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**Resources**

Carolina Biological Supply—[www.carolina.com](http://www.carolina.com)


Nasco (scientific supply company)—[www.enasco.com](http://www.enasco.com)

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**Deena Gould** (DNAmartin@cox.net) was a science and language teacher in Mesa Public Schools from 1987 to 2012. She is currently a graduate student in the Mary Lou Fulton College of Education at Arizona State University in Tempe, Arizona.
Activity Worksheet: Seeding Argumentation About Cells and Growth

Activity 1: Is a seed alive?

Day 1

1. What was your position on the continuum? Mark your position with an X.

Is a seed alive?
Yes, definitely ______________ No, definitely not

2. What was your thinking? What ideas did you have about the seeds that explain your thinking? What information or evidence would convince you to move further along the continuum? Write your main topic statement and supporting details in complete sentences.

Vocabulary: seed, alive, thinking, reasoning, justification

[Common Core connection—CCSS.ELA-Literacy. WHST.6-8.2d: Use precise language and domain-specific vocabulary to inform about or explain the topic (NGAC and CCSSO 2010).]

3. What different ideas were discussed in your group? Which ideas were similar to yours? Which ideas were different from yours? What justifications did you share with the group? What justifications did you hear from others in your group? Did you change your thinking? Why or why not? What information or evidence would your team need to make a claim about whether or not these seeds are alive?

Vocabulary: seed, alive, thinking, reasoning, justification, claim, evidence

[Common Core connection—CCSS.ELA-Literacy. WHST.6-8.10: Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks and purposes (NGAC and CCSSO 2010).]

Day 2: Designing the apparatus

Materials (per group):
- 2 clear plastic cups
- Paper towels
- 2 cups of soil
- 2 rulers
- 6 popcorn seeds
- Water
- Graduated cylinder or other tool for measuring volume
- Permanent marker to label cups
- Chemical splash safety goggles

Directions

Design an apparatus that will enable your team to observe, measure, and make inferences about the seeds over the next three weeks. Design your apparatus for making scientific observations. Make a labeled sketch of your design in your lab notebook. Construct your device and plant your seeds.

Vocabulary: apparatus, volume, mL, soil, seed, scientific observations
Let's talk science: seeding argumentation about cells and growth

Day 3: Designing the chart
Design a chart or note-taking format that your team will use to record observations, measurements, and inferences over the next three weeks. Discuss the answers to the following questions with your group:

- What main headings will you use?
- What variables could you observe and measure?
- What units of measurement will you use?
- What data will you record?
- What measurements and observations might help you determine if the seeds are alive?

After discussing the answers to these questions with your group, prepare your chart, table, or note-taking format.

Vocabulary: measurement, inferences, facts, reasoned judgment, speculation, unit of measurement, decimal

[Common Core connection—CCSS.ELA-Literacy. WHST.6-8.2a: Organize ideas, concepts, and information into broader categories as appropriate to achieving purpose; include formatting (e.g., headings), graphics (e.g., charts, tables), when useful to aiding comprehension (NGAC and CCSSO 2010).]

Days 4–21: Recording data and making inferences
[Recording data should only take a few minutes each day. It could be done during warm-up so that the remaining time of each class period could be used to keep pace with the rest of the curriculum. Teachers may choose to end this activity at day 14 when most viable seeds have germinated (when the white radicle or root breaks through and emerges from the seed coat); however, additional time will enable students to investigate more deeply, gain curiosity about growth, and engineer a better apparatus. Not all seeds will be viable, so some groups might need encouragement and time to try again.]

Use the chart your group designed to record data. Make close, detailed, and careful observations. Some changes may be very small. If possible, use a magnifying lens or stereo-microscope to aid in making your observations. What do you think the observations mean? Include a section or column for inferences. What do you think counts as evidence that the seeds are or are not alive? What inferences can you make about the changes you observe? Does your apparatus enable you to observe and measure the seeds? How could you improve your apparatus? If time allows, change your apparatus and acquire more seeds. Role-playing science talk with your group will give you ideas for your interpretations or inference section.

Vocabulary: inference, interpretation, evidence, seed coat, embryo, root, shoot, germination, grow, seedling, change over time, facts, reasoned judgment, speculation

[Common Core connection—CCSS.ELA-Literacy. WHST.6-8.2: Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. CCSS.ELA-Literacy.RST.6-8.8: Distinguish among facts, reasoned judgment based on research findings, and speculation (NGAC and CCSSO 2010).]
Activity 2: Microscope investigation
[This activity typically takes four full class periods and begins around day 20, when many seeds have germinated and begun to grow, however it could begin as early as day 14 and as late as day 25.]

Before using the microscope:
The compound microscope can enlarge your view 250 to 400 times. How could the microscope aid you in understanding the changes in your seeds? What do you think is happening at the microscopic level that enables your seeds to grow? Write your main topic statement and supporting details in complete sentences. Explain your reasoning.

[Common Core connection—CCSS.ELA-Literacy.WHST.6-8.10: Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences (NGAC and CCSSO 2010).]

Using the microscope:
Materials (per group)
• Compound microscope,
• Prepared slide of onion root mitosis

Directions:
Observe the prepared slides of onion root tips. Make labeled sketches of at least five cells. Label the structures inside the cells. What do you think is happening at the cellular level that enables the root to grow? Record data, observations, and inferences in an organized format. What variables could you count or measure to figure out what is happening? How might the cells or data relate to each other? How could you organize your data to make sense of what it means? Role-play discourse situations with your group to give you ideas for recording your observations, inferences, and analysis.

[Common Core connection—CCSS.ELA-Literacy.WHST.6-8.2a: Introduce a topic clearly, previewing what is to follow; organize ideas, concepts, and information into broader categories as appropriate to achieving purpose; include formatting (e.g., headings), graphics (e.g., charts, tables), when useful to aiding comprehension (NGAC and CCSSO 2010).]

Activity 3: Scientific argument from evidence
[This activity requires three or four class periods.]

Use the format below and the discussion with your group to prepare an argument.

Claim: What is the best explanation?

Evidence: What observations, information, or data analysis support the claim?

Reasoning: What is the justification that tells why the data support the claim?

[Common Core connections—CCSS.ELA-Literacy.WHST.6-8.1: Write arguments focused on discipline-specific content. CCSS.ELA-Literacy.WHST.6-8.1b: Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic. CCSS.ELA-Literacy.WHST.6-8.1c: Use words, phrases, and clauses to create cohesion and clarify the relationships among claim(s), reasons, and evidence. CCSS.ELA-Literacy.WHST.6-8.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience (NGAC and CCSSO 2010).]
**Advance Registration Form**

**NSTA 2013 Area Conferences**

Portland, OR • Oct. 24–26         Charlotte, NC • Nov. 7–9        Denver, CO • Dec. 12–14

---

### Membership Status
- [ ] I am a member of NSTA. Member ID # ________________
- [ ] I am not a member of NSTA but wish to join. I have included my membership application* and dues with my registration payment.
- [ ] I am not a member of NSTA.

*see following pages

### Personal Information
Please print or type. Information with an asterisk (*) will appear on your badge.

- **First Name**: ___________________________*_  **MI**: ___________  **Last Name**: ___________________________*_
- **Job Position/Title**: ___________________________*_
- **Name of Institution/Affiliation**: ___________________________*_
- **City**: ___________________________*_  **State/Province**: ___________  **Country**: ___________  **Zip**: ___________
- **Home Mailing Address**: ___________________________*_
- **City**: ___________________________*_  **State/Province**: ___________  **Country**: ___________  **Zip**: ___________
- **I prefer to receive mail at:**  [ ] Home  [ ] Work  
- **Daytime phone**: ___________________________*_  **Fax**: ___________  **E-mail**: ___________________________*_
- **Name of spouse/guest attending conference with you**: ___________________________*_

Name(s) of children attending conference with you (high school age and under register for free)

- [ ] Check here if you need SPECIAL ASSISTANCE due to a disability. Attach an extra sheet describing assistance needed, including evening phone number. *We may NOT be able to arrange special services for requests received after the advance deadline.*

---

### Disciplines (check all that apply)
- Earth Science
- Computer Science
- Biology
- Tech. Education
- Chemistry
- Physics
- Environmental Science
- Physical Science
- General Science
- Other

### Position (check all that apply)
- Teacher
- Scientist
- Professor
- Student
- Dept. Head/Chair
- Consultant
- Principal
- Supervisor/Coordinator
- Administrator
- Professional Develop. Provider
- Other

### Grades (check all that apply)
- PreK–K
- 1st Grade
- 2nd Grade
- 3rd Grade
- 4th Grade
- 5th Grade
- 6th Grade
- 7th Grade
- 8th Grade
- 9th Grade
- 10th Grade
- 11th Grade
- 12th Grade

### Institution (check all that apply)
- Public School
- Private School
- 2-year College
- 4-year College
- Graduate School
- Business
- Retired
- Laboratory
- Informal Education
- Home School
- Library
- Other

---

### Registration Fees

**Check one city only. Circle selected fees.**

<table>
<thead>
<tr>
<th>Fee Category</th>
<th>Earlybird</th>
<th>Advance</th>
<th>Full Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charlotte</td>
<td>9/20/13</td>
<td>10/11/13</td>
<td>11/22/13</td>
</tr>
</tbody>
</table>

**Two to Three Days**
- Current NSTA member or applicant: $175  
- Chapter member: $175  
- OSTA (OR) *WSTA (WA) NCSTA (NC)*: $175  
- ACS member #: $175  
- AAPT member #: $175  
- NABT member #: $175 (available for Denver only)
- Nonmember: $265  
- Retired NSTA member #: $115  
- Full-time Student: $90

**One Day Only—Check Day:**
- Thu & Fri:  
  - Nonstudent (member or nonmember): $160  
  - Full-time Student: $65
- Last Day Only—Saturday:  
  - Nonstudent (member or nonmember): $95  
  - Full-time Student: $35

**Nonteaching Spouse/Guest** (enter name above)
- $85

---

### Program/Ticket Information

- [ ] Check here if you would like to GO GREEN and PAPERLESS and receive an electronic version (PDF) of the final conference program. This PDF will be sent via e-mail approximately two weeks before the conference. (See reverse for details.)

**Ticket information for short courses, field trips, and networking events will be available online in late July.**

---

### Payment

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Registration Fee</td>
<td>$ ______</td>
</tr>
<tr>
<td>Spouse/Guest Fee</td>
<td>$ ______</td>
</tr>
<tr>
<td>Membership Fee (form attached)</td>
<td>$ ______</td>
</tr>
<tr>
<td>Total Due</td>
<td>$ ______</td>
</tr>
</tbody>
</table>

I am paying by:
- [ ] Check #_____ (payable to “National Science Teachers Association” in U.S. funds)
- [ ] School Purchase Order (copy attached):
  - PO No.: __________

Please note that credit card payments for conference registration must be made online at:  

[www.nsta.org/conferences](http://www.nsta.org/conferences)

---

**Mail your completed form with payment to National Science Teachers Association, Conference Dept., PO Box 90214, Washington, DC 20090-0214, FAX: 703-243-3924, or register online at [www.nsta.org/conferences](http://www.nsta.org/conferences).**
Registration Instructions
This form is for the use of conference participants only. Individuals registering to conduct business should contact Rick Smith, Director, NSTA Exhibits and Advertising, at 703-312-9282 or 703-599-3520 (cell) to register as a Non-exhibiting Industry Representative.

Each registrant (except nonteaching spouse) must submit a separate registration form. Do not send duplicate registrations—If you fax your form, do not also mail the form.

Registration fees cover all nonticketed conference activities and entry to the Exhibit Hall. Fees do not cover ticketed events, meals, lodging, or transportation other than NSTA-contracted shuttle service.

By registering to attend a National Science Teachers Association (NSTA) conference, you grant permission to NSTA to take and use your photo in NSTA marketing and promotional pieces for an indefinite period of time. Marketing and promotional pieces include, but are not limited to, printed brochures, reports, postcards, flyers, and materials, as well as online uses such as postings on the NSTA website, online newsletters, and e-mail blasts. NSTA shall own all rights, including copyrights in and to the photos.

Registration Rates
The member rate:
Only those individuals listed below may register at the NSTA member rate:

- Current NSTA members
- Nonmembers who submit an NSTA membership application and membership fee along with the registration form
- Members of the Colorado Association of Science Teachers (CAST) (Denver conference only)
- Members of the North Carolina Science Teachers Association (NCSTA) (Charlotte conference only)
- Members of the Oregon Science Teachers Association (OSTA) (Portland conference only)
- Members of the South Carolina Science Council (SCSC) (Charlotte conference only)
- Members of the Washington Science Teachers Association (WSTA) (Portland conference only)
- Members of the American Association of Physics Teachers (AAPT)
- Members of the American Chemical Society (ACS)
- Members of the National Association of Biology Teachers (NABT) (Denver conference only)

The retired member rate:
NSTA members who are fully retired and have been an NSTA member for at least five years may register at the retired rate.

The student rate:
Full-time students 18 years of age or older may register at the student rate if the registration form is accompanied by a copy of a current university ID or a letter from the university indicating full-time enrollment.

Spouse/Guest/Children Attending Conference with You
Your nonteaching spouse/guest and children must be registered in order to visit the Exhibit Hall but do not need to submit separate registration forms. Please provide their names on your own registration form. Children of high school age and under can be registered for free. A fee is required for your spouse/guest. College students and teaching spouses must submit separate registration forms and payment.

Earlybird/Advance Deadlines
Registrations submitted online, postmarked, or faxed by the earlybird deadline or the advance deadline have substantially lower fees than those for on-site registration.

You must register by the advance deadline to receive your badge, tickets, and confirmation in advance of the conference. If you submitted your registration before the advance deadline and if by three weeks before the conference you have not received your confirmation packet, call NSTA conference registration at 703-243-7100 or 800-328-8998 or e-mail reg@nsta.org.

If your registration is received online or postmarked/faxed after the advance deadline, you will be charged the full on-site rate and your confirmation may not be mailed to you before the conference. Pick up your confirmation, badges, and tickets on-site at the Conference Services Counter in the NSTA Registration Area.

Go Green! Final Programs by E-Mail
Registrants who check the box on the front of this form in the Program/Ticket Information section will receive an electronic version (PDF) of the program by e-mail approximately two weeks prior to the conference. Also, take advantage of our online conference scheduler to plan your itinerary before you arrive at the conference.

Ticketed Events
Tickets for short courses, field trips, networking events, and other special events will be available for purchase in late July. You may register for the conference using this Advance Registration Form and add tickets to your registration later by submitting a new registration form (check the box on the new form that indicates that you have already registered for the conference). In late July, details and descriptions of ticketed events will be available on our website (www.nsta.org/conferences). Tickets are nonrefundable.

Submitting Your Registration
Payment for registration and membership (if attaching membership application) must be included with your registration form. Forms received without payment will be returned unprocessed. Payment may be made by check or purchase order from your school or school district (attach forms for all registrants). Mail your completed form with check payment to:

National Science Teachers Association
Conference Department
PO Box 90214
Washington, DC 20090-0214
FAX: 703-243-3924

Please note that online registration (www.nsta.org/conferences) is required for payment made by credit card.

Refund/Cancellation Policy
Refund requests must be in writing and must be postmarked 10 days before the conference. Badge materials must be returned with refund request. Registration cancellations are subject to a $20 processing fee. Ticketed events are nonrefundable.

Questions?
Contact NSTA conference registration at 703-243-7100 or 800-328-8998, or via e-mail at reg@nsta.org. For general information on the fall conferences or to register online, visit our website at www.nsta.org/conferences.
Get Great Benefits All Year Long—Join NSTA Today and Save!

Gain year-round access to the latest news and information affecting science education.

1. **Membership Options** Each membership option listed below includes one journal.
   - Individual Membership—$75/yr.
   - Student—$35/yr. For students enrolled in an accredited college or university as a student with an interest in science education only. Include proof of current registration with your payment. Instructor must sign here:
   - New Teacher—$35/yr. Teachers who are in their first five years of teaching. Send a copy of your teaching certificate or a letter from your administrator.
   - International Regular Membership—$90/yr. (one journal only)
   - International Electronic Membership—$35/yr. (no hard copy journal and no U.S. addresses)
   - Retired—$35/yr. Science educators who are fully retired and have been an NSTA member for at least five years.
   - Joint NSTA/OSTA—$95/yr. Includes membership in both Oregon Science Teachers Association and NSTA (OSTAF13).
   - Joint NSTAA/WSTA—$85/yr. Includes membership in both Washington Science Teachers Association and NSTA (WSTAF13).

2. **Contact Information** (please print)
   - Name __________________________
   - Title __________________________
   - Institution ______________________
   - Home ° Work °
   - Address ____________________________________________________________
   - City __________________ State ______ Zip __________
   - Country __________________________
   - Work Phone ________________________
   - Home Phone ________________________
   - Fax ______________________________
   - E-mail ____________________________

Have you ever been an NSTA member?
   - No ° Yes ID# ________________________
   - Please remove my name and postal address from the mailing list NSTA makes available to other organizations.

3. **Membership Journals** Select the journal you would like to receive as part of your membership:
   - Science & Children—9 times a year; grades K–6
   - Science Scope—9 times a year; grades 6–9
   - The Science Teacher—9 times a year; grades 9–12
   - Journal of College Science Teaching—6 times a year; college

To subscribe to more than one journal, call NSTA Member Services at 800-722-NSTA (6782) or 703-243-7100.

4. **GRADES** (check all that apply)
   - Pre-K ° 4th Grade ° 9th Grade
   - Kindergarten ° 5th Grade ° 10th Grade
   - 1st Grade ° 6th Grade ° 11th Grade
   - 2nd Grade ° 7th Grade ° 12th Grade
   - 3rd Grade ° 8th Grade ° College

5. **DISCIPLINES** (check all that apply)
   - Earth and Space Science ° Physical Science
   - Biology/Life Science ° General Science
   - Chemistry ° Computer Science
   - Physics ° Tech Education
   - Environmental Science ° Other __________________________

6. **Payment Method**
   - School Purchase Order enclosed. PO# __________________________
   - Check enclosed, payable to NSTA (U.S. Dollars)
   - Please charge my credit card: MasterCard ° VISA ° Discover ° AMEX
   - Card # ___________________________ Expiration Date __________________________
   - Name on card ___________________________ Signature __________________________

Four Easy Ways to Join NSTA
1. Visit www.nsta.org
2. Fax your completed form to 703-243-3924
3. Mail your completed form with payment to NSTA, P.O. Box 90214, Washington, DC 20090-0214.
4. Call NSTA Member Services at 800-722-NSTA (6782) or 703-243-7100.

Membership dues are subject to change without notice.
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   - Student—$35/yr. For students enrolled in an accredited college or university as a student with an interest in science education only. Include proof of current registration with your payment. Instructor must sign here:
   - New Teacher—$35/yr. Teachers who are in their first five years of teaching. Send a copy of your teaching certificate or a letter from your administrator.
   - International Regular Membership—$90/yr. (one journal only)
   - International Electronic Membership—$35/yr. (no hard copy journal and no U.S. addresses)
   - Retired—$35/yr. Science educators who are fully retired and have been an NSTA member for at least five years.
   - Joint NSTA/NCSTA—$90/yr. Includes membership in both Georgia Science Teachers Association and NSTA (NCSTAF13).
   - Joint NSTA/SCSC—$75/yr. Includes membership in both South Carolina Science Council and NSTA (SCSCF13).

2. **Contact Information** (please print)
   - Name _________________________
   - Title _________________________
   - Institution _________________________
   - Home ☐ Work ☐
   - Address _________________________
   - City _________________________ State ________ Zip __________
   - Country _________________________
   - Work Phone _________________________
   - Home Phone _________________________
   - Fax _________________________
   - E-mail _________________________

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   - Science Scope—9 times a year; grades 6–9
   - The Science Teacher—9 times a year; grades 9–12
   - Journal of College Science Teaching—6 times a year; college

To subscribe to more than one journal, call NSTA Member Services at 800-722-NSTA (6782) or 703-243-7100.

4. **GRADES** (check all that apply)
   - Pre-K ☐ 4th Grade ☐ 9th Grade ☐
   - Kindergarten ☐ 5th Grade ☐ 10th Grade ☐
   - 1st Grade ☐ 6th Grade ☐ 11th Grade ☐
   - 2nd Grade ☐ 7th Grade ☐ 12th Grade ☐
   - 3rd Grade ☐ 8th Grade ☐ College ☐

5. **DISCIPLINES** (check all that apply)
   - Earth and Space Science ☐ Physical Science ☐
   - Biology/Life Science ☐ General Science ☐
   - Chemistry ☐ Computer Science ☐
   - Physics ☐ Tech Education ☐
   - Environmental Science ☐ Other________________________

6. **Payment Method**
   - School Purchase Order enclosed. PO# _________________________
   - Check enclosed, payable to NSTA (U.S. Dollars)
   - Please charge my credit card: ☐ MasterCard ☐ VISA ☐ Discover ☐ AMEX
   - Card # _________________________ Expiration Date _________________________
   - Name on card _________________________ Signature _________________________

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   - New Teacher—$35/yr. Teachers who are in their first five years of teaching. Send a copy of your teaching certificate or a letter from your administrator.
   - International Regular Membership—$90/yr. (one journal only)
   - International Electronic Membership—$35/yr. (no hard copy journal and no U.S. addresses)
   - Retired—$35/yr. Science educators who are fully retired and have been an NSTA member for at least five years.
   - Joint NSTA/CAST—$80/yr. Includes membership in both Colorado Association of Science Teachers and NSTA (CASTF13).

2. **Contact Information** (please print)

   - Name ________________________________
   - Title ________________________________
   - Institution ____________________________
   - Home Q Work Q
   - Address ______________________________________________________
   - City __________________ State ________ Zip ________________
   - Country ____________________________
   - Work Phone ____________________________
   - Home Phone ____________________________
   - Fax ________________________________
   - E-mail ________________________________

   - Have you ever been an NSTA member?
   - No Q Yes Q

   - Please remove my name and postal address from the mailing list NSTA makes available to other organizations.

3. **Membership Journals** Select the journal you would like to receive as part of your membership:
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   - Science Scope—9 times a year, grades 6–9
   - The Science Teacher—9 times a year, grades 9–12
   - Journal of College Science Teaching—6 times a year, college

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4. **GRADES** (check all that apply)
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   - Kindergarten Q 5th Grade Q 10th Grade
   - 1st Grade Q 6th Grade Q 11th Grade
   - 2nd Grade Q 7th Grade Q 12th Grade
   - 3rd Grade Q 8th Grade Q College

5. **DISCIPLINES** (check all that apply)
   - Earth and Space Science Q Physical Science
   - Biology/Life Science Q General Science
   - Chemistry Q Computer Science
   - Physics Q Tech Education
   - Environmental Science Q Other______________________

6. **Payment Method**
   - School Purchase Order enclosed. PO#
   - Check enclosed, payable to NSTA (U.S. Dollars)
   - Please charge my credit card: Q MasterCard Q VISA Q Discover Q AMEX
   - Card #__________________________________ Exp. Date ________________
   - Name on card ____________________________ Signature __________________

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1. Visit www.nsta.org
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3. Mail your completed form with payment to NSTA, P.O. Box 90214, Washington, DC 20090-0214.
4. Call NSTA Member Services at 800-722-NSTA (6782) or 703-243-7100.

Membership dues are subject to change without notice.
Official Housing Request Form for payment by checks only
October 24–26, 2013, Portland, Oregon

CONTACT INFORMATION
First: __________________________ Mi: _______ Last: __________________________
E-mail: __________________________
School/Company: __________________________
Address: __________________________
City: __________________________ State: _______ Postal Code: __________________________
Country: __________________________
Phone: _______________ Fax: __________________________

HOTEL SELECTION
Arrival Date: __________________________ Departure Date: __________________________

HOTEL | SINGLE | DOUBLE | TRIPLE | QUAD
---|---|---|---|---
1. DoubleTree by Hilton Hotel Portland (Headquarters Hotel) | $137 | $137 | $137 | $137
2. Red Lion Hotel Portland Convention Center | $109 | $109 | $109 | $109
3. Hilton Portland & Executive Tower (Main Building) | $149 | $149 | $149 | $149
(Tower) | $159 | $159 | $159 | $159

Please select hotel choices in order of preference and enter their numbers below.
1st __________________________ 2nd __________________________

Room Type Requested: ☐ One Bed  ☐ Two Beds

If requested hotels are unavailable, a reservation will be made at the next available hotel. Please select criteria: ☐ Comparable room rate  ☐ Proximity to conference site

Submit only one room request per form. Should additional forms be needed, please make copies.

List all room occupants (include yourself):
________________________________________
________________________________________
________________________________________

☐ Check here if you require special services  (*Note: By state law, all rooms are nonsmoking.)

Special requests: __________________________

DEPOSIT INFORMATION
All reservation requests must be accompanied by a check for one night’s deposit. To pay with credit card, go online to www.nsta.org/portlandhousing.

Check deposits must be mailed with a completed housing form. After receiving payment, the Housing/Next Door will process the deposit. If the check is returned, a new check must be mailed. If a reservation is not confirmed within 48 hours of arrival, the deposit will be forfeited.

☐ One night’s check deposit enclosed and made payable to Orchard Event Solutions. Mail housing forms to Orchard Event Solutions–NSTA/Portland, 175 South West Temple, Suite 140, Salt Lake City, UT 84101.

Check deposits must be received by September 27 to be accepted.

Deadline: September 27, 2013

Instructions:
Housing reservations can be made in one of the following ways beginning June 11.

• INTERNET * Preferred
  For payments via credit card

  www.nsta.org/PortlandHousing
  Please have your credit card and arrival/departure information ready. Accepted credit cards include American Express, Diner's Club, Discover, Master Card, and Visa.

• TELEPHONE
  877-352-6710 (toll free)
  801-505-4611 (international)
  Call between 7:00 AM and 6:00 PM Mountain Time, Monday–Friday. Be prepared to provide all the information on this form.

• MAIL (Use one form per room request)
  DO NOT MAIL TO NSTA
  *Mail checks only to:
  Orchid Event Solutions–NSTA/Portland
  175 South West Temple, Suite 140
  Salt Lake City, UT 84101

DEADLINE
Reservations must be made by September 27, 2013.

CONFIRMATIONS
Orchid Event Solutions (formerly The Housing Connection) will send you a confirmation of your reservation. Please review all information for accuracy. E-mail confirmation will be sent if an e-mail address is provided (preferred), or confirmation can be faxed or mailed. If you do not receive a confirmation or if you have questions, call Orchid Event Solutions. You will NOT receive a confirmation from the hotel.

TAX RATE and SPECIAL REQUESTS
All rates are per room and are subject to a 14.5% tax (occupancy, city, and state and are subject to change). Special requests cannot be guaranteed; however, hotels will do their best to honor all requests. Hotels will assign specific room types upon check-in, based on availability.

ROOM DEPOSIT REQUIRED TO SECURE RESERVATION
All reservations must be accompanied by a valid credit card guarantee or deposit will not be processed. Check deposits must be mailed with a completed housing form payable to "Orchid Event Solutions."

CANCELLATION POLICY
Cancellations made after September 27 and prior to 48 hours before arrival date will be subject to a $25 cancellation fee. One night’s room charge and tax will be forfeited entirely if cancellation occurs within 48 hours of arrival.
Deadline: 
October 7, 2013

INSTRUCTIONS
Housing reservations can be made in one of the following ways beginning June 11.

• INTERNET * Preferred
  For payments via credit card
  www.nsta.org/charlottehousing
  Please have your credit card and arrival/departure information ready. Accepted credit cards include American Express, Diner’s Club, Discover, Master Card, and Visa.

• TELEPHONE
  877-352-6710 (toll free)
  801-505-4611 (international)
  Call between 7:00 AM and 6:00 PM Mountain Time, Monday—Friday. Be prepared to provide all the information on this form.

• MAIL (Use one form per room request)
  DO NOT MAIL TO NSTA
  *Mail CHECKS ONLY to:
  Orchard Event Solutions—NSTA/Charlotte
  175 South West Temple, Suite 140
  Salt Lake City, UT 84101

DEADLINE
Reservations must be made by October 7, 2013.

CONFIRMATIONS
Orchid Event Solutions (formerly The Housing Connection) will send you a confirmation of your reservation. Please review all information for accuracy. E-mail confirmation will be sent if an e-mail address is provided (preferred), or confirmation can be faxed or mailed. If you do not receive a confirmation or if you have questions, call Orchid Event Solutions. You will NOT receive a confirmation from the hotel.

TAX RATE and SPECIAL REQUESTS
All rates are per room and are subject to a 15.25% tax (occupancy, city, and state and are subject to change). Special requests cannot be guaranteed; however, hotels will do their best to honor all requests. Hotels will assign specific room types upon check-in, based on availability.

ROOM DEPOSIT REQUIRED TO SECURE RESERVATION
All reservations must be accompanied by a valid credit card guarantee or check for one night’s deposit. Housing Forms received without a valid guarantee or deposit will not be processed. Check deposits must be mailed with a completed housing form payable to “Orchid Event Solutions.”

CANCELLATION POLICY
Cancellations made after October 7 and prior to 48 hours before arrival date will be subject to a $25 cancellation fee. One night’s room charge and tax will be forfeited entirely if cancellation occurs within 48 hours of arrival.

Check deposits must be mailed with a completed housing form. After receiving payment, Orchid Event Solutions or any one of the participating hotels will process a charge for each room deposit in accordance with the policies and information provided herein no sooner than October 7, 2013.

Check deposits must be received by October 7 to be accepted.

www.nsta.org/charlottehousing: Suggested Method for Housing Reservations

NSTA Charlotte Area Conference

Official Housing Request Form
for payment by checks only

November 7–9, 2013, Charlotte, North Carolina

CONTACT INFORMATION

First: ___________________________ MI: _______ Last: ___________________________

E-mail: ___________________________

School/Company: ___________________________

Address: ___________________________

City: ___________________________ State: _______ Postal Code: ___________________________

Country: ___________________________

Phone: ___________________________ Fax: ___________________________

HOTEL SELECTION

Arrival Date: ___________ Departure Date: ___________

<table>
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<tr>
<th>HOTEL</th>
<th>SINGLE</th>
<th>DOUBLE</th>
<th>TRIPLE</th>
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</tr>
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<tr>
<td>1. The Westin Charlotte (Headquarters Hotel)</td>
<td>$175</td>
<td>$175</td>
<td>$185</td>
<td>$185</td>
</tr>
<tr>
<td>2. Hilton Garden Inn Charlotte Uptown</td>
<td>$119</td>
<td>$119</td>
<td>$119</td>
<td>$119</td>
</tr>
<tr>
<td>3. Hampton Inn Charlotte–Uptown</td>
<td>$119</td>
<td>$119</td>
<td>$119</td>
<td>$119</td>
</tr>
<tr>
<td>4. Hilton Charlotte Center City</td>
<td>$155</td>
<td>$155</td>
<td>$175</td>
<td>$175</td>
</tr>
</tbody>
</table>

Rates include free internet. A map showing hotel locations is available at www.nsta.org/charlottehousing.

Please select hotel choices in order of preference and enter their numbers below.

1st ___________________________ 2nd ___________________________

Room Type Requested: ☐ One Bed  ☐ Two Beds
If requested hotels are unavailable, a reservation will be made at the next available hotel.
Please select criteria:  ☐ Comparable room rate  ☐ Proximity to conference site
Submit only one room request per form. Should additional forms be needed, please make copies.

List all room occupants (include yourself):

__________________________________________  ___________________________

☐ Check here if you require special services  ☐ Nonsmoking request

Special requests: ___________________________

DEPOSIT INFORMATION

All reservation requests must be accompanied by a check for one night’s deposit. To pay with credit card, go online to www.nsta.org/charlottehousing.

Check deposits must be mailed with a completed housing form. After receiving payment, Orchid Event Solutions or any one of the participating hotels will process a charge for each room deposit in accordance with the policies and information provided herein no sooner than October 7, 2013.

☐ One night’s check deposit enclosed and made payable to Orchid Event Solutions. Mail housing forms to Orchid Event Solutions–NSTA/Charlotte, 175 South West Temple, Suite 140, Salt Lake City, UT 84101.

Check deposits must be received by October 7 to be accepted.
INSTRUCTIONS
Housing reservations can be made in one of the following ways beginning June 11.

• INTERNET * Preferred
  For payments via credit card
  www.nsta.org/denverhousing
  Please have your credit card and arrival/departure information ready. Accepted credit cards include American Express, Diner’s Club, Discover, Master Card, and Visa.

• TELEPHONE
  888-421-1442 (toll free)
  402-592-6464 (international)
  Call Monday–Friday (available 24 hours).
  Be prepared to provide all the information on this form.

• MAIL (Use one form per room request)
  DO NOT MAIL TO NSTA
  *Mail CHECKS ONLY to:
  Hyatt Regency Denver—NSTA Reservations
  650 15th St.
  Denver, CO 80202

DEADLINE
Reservations must be made by November 13, 2013.

CONFIRMATIONS
After your reservation has been made, you will receive a confirmation of your reservation. Please review all information for accuracy. E-mail confirmation will be sent only if an e-mail address is provided. If you do not receive a confirmation or if you have questions, call the telephone numbers listed above. You will NOT receive a confirmation from the hotel.

TAX RATE and SPECIAL REQUESTS
All rates are per room and are subject to a 14.75% tax (occupancy, city, and state and are subject to change). Special requests cannot be guaranteed; however, the hotel will do their best to honor all requests. The hotel will assign specific room types upon check-in, based on availability.

ROOM DEPOSIT REQUIRED TO SECURE RESERVATION
All reservations must be accompanied by a valid credit card guarantee or check for one night’s deposit. Housing Forms received without a valid guarantee or deposit will not be processed. Check deposits must be mailed with a completed housing form payable to “Hyatt Regency Denver.”

CANCELLATION POLICY
One night’s room charge and tax will be forfeited entirely if cancellation occurs within 48 hours of arrival.

CONTACT INFORMATION
First: _____________________ Mi: _______ Last: _____________________
E-mail: _____________________
School/Company: _____________________
Address: _____________________
City: _____________________ State: _______ Postal Code: _____________________
Country: _____________________
Phone: _____________________ Fax: _____________________

HOTEL SELECTION
Arrival Date: ________________ Departure Date: ________________

<table>
<thead>
<tr>
<th>HOTEL</th>
<th>SINGLE</th>
<th>DOUBLE</th>
<th>TRIPLE</th>
<th>QUAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hyatt Regency Denver at Colorado Convention Center (Headquarters)</td>
<td>$122</td>
<td>$122</td>
<td>$137</td>
<td>$152</td>
</tr>
</tbody>
</table>

A map showing hotel location is available at www.nsta.org/denverhousing.

Room Type Requested: ☐ One Bed  ☐ Two Beds

Submit only one request per form. Should additional forms be needed, please make copies.

List all room occupants (include yourself):

________________________________________________________

☐ Check here if you require special services  ☐ Nonsmoking request

Special requests: ______________________________________

DEPOSIT INFORMATION
All reservation requests must be accompanied by a check for one night’s deposit. To pay with credit card, go online to www.nsta.org/denverhousing.

Check deposits must be mailed with a completed housing form. After receiving payment, the Hyatt Regency Denver will process a charge for each room deposit in accordance with the policies and information provided herein no sooner than November 13, 2013.

☐ One night’s check deposit enclosed and made payable to Hyatt Regency Denver. Mail housing forms to Hyatt Regency Denver—NSTA Reservations, 650 15th St., Denver, CO 80202. Check deposits must be received by November 13 to be accepted.
Can you hear me now?

by Ken Roy

If there is a serious safety or security incident in the science laboratory, such as a fire, an explosion, or two students with injuries, does the science teacher have the capability to contact the office? What about during a field trip either on- or off-site? What if a student or the teacher gets hurt and needs emergency assistance? What if there is a lockdown at the school? Is there a means of communication for the science teacher out in the field so incident protocols can be followed? If the answers to these questions are no, the teacher’s and students’ safety is at risk.

Dialing in to the standards and practices

First of all, are there any legal standards or professional best practices addressing this need for a means of communication? The answer is yes. One legal standard is noted in the Occupational Safety and Health Administration’s (OSHA’s) standards regarding employee alarm systems (1910.165[b][1]), which state the following: “The employee alarm system shall provide warning for necessary emergency action as called for in the emergency action plan, or for reaction time for safe escape of employees from the work- place or the immediate work area, or both.” If a science class is out in the field on school grounds but out of audible range of the fire alarm or a lockdown or lockout announcement, there needs to be a means of providing warning with a two-way radio or cell phone.

In the OSHA booklet titled “How to Plan for Workplace Emergencies and Evacuations,” the specifics for either reporting or being made aware of a safety or security problem are addressed. OSHA states that at a minimum, the emergency action plan must include the following:

• a preferred method for reporting fires and other emergencies;
• an evacuation policy and procedure;
• emergency escape procedures and route assignments, such as floor plans, workplace maps, and safe or refuge areas;
• names, titles, departments, and telephone numbers of individuals both within and outside your company to contact for additional information or explanation of duties and responsibilities under the emergency plan;
• procedures for employees who remain to perform or shut down critical plant operations, operate fire extinguishers, or perform other essential services that cannot be shut down for every emergency alarm before evacuating; and
• rescue and medical duties for workers designated to perform them” (2001).
The booklet further states that the plan must include a means of alerting employees on how to evacuate or take other action and how to report emergencies. The following steps must be taken:

- “Make sure alarms are distinctive and recognized by all employees as a signal to evacuate the work area or perform actions identified in your plan.
- Make available an emergency communications system such as a public address system, portable radio unit, or other means to notify employees of the emergency and to contact local law enforcement, the fire department, and others.
- Stipulate that alarms must be able to be heard, seen, or otherwise perceived by everyone in the workplace. You might want to consider providing an auxiliary power supply in the event that electricity is shut off” (1910.165[b][2]).

Given the risk of a safety or security incident in a middle school science lab or out in the field, science teachers need to first make sure they have been proactive in case of an emergency. This includes having a means of direct communication with the office and outside emergency responders such as the local police or fire department. School communications might include an intercom in the lab and a phone. Out in the field, a cell phone or two-way radio is effective for communication. Always have emergency numbers of police, fire, school nurse, administration, and others contacts critical to a safety or security situation. Make sure protocols are established for periodic testing of communications systems. Usually the facilities department is responsible for this action, and the local fire marshal inspects for posting of emergency evacuation routes from laboratories and classrooms. However, the board of education is responsible for postings and drills during the school year.

**Bottom line**

Effective employee communication during an emergency is of utmost importance. Where possible, multiple communication methods should be available in case of technology failures due to an emergency or other catastrophic conditions. If not available, teachers should advise the administration or their union/association in writing. Should there still be no action, teachers have the option of contacting OSHA (providing they are under OSHA’s jurisdiction), local fire marshal, or the school’s insurance company. Science teachers need to be advocates for communication methods in their school’s incident protocols.

**Question of the month**

With the revision of OSHA’s Hazard Communication Standard, do chemicals purchased before the effective revision date (May 25, 2012) need to have their labels updated to meet the Globally Harmonized System of Classification and Labeling of Chemicals (GHS) format?

**Answer**

According to OSHA, no update is necessary if the chemical is stored in its original container or bottle. On the other hand, if the contents are moved to a secondary container or bottle, the updated GHS labeling requirements must be followed.

**Do you have a safety question?**

Submit questions relative to safety in the middle school science laboratory to Ken Roy at Royk@glastonbury.us.org.

**References**


Ken Roy (Royk@glastonbury.us.org) is director of environmental health and safety for Glastonbury Public Schools in Glastonbury, Connecticut, and NSTA’s science safety compliance consultant.
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• Moderated by world-renowned faculty
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http://learningcenter.nsta.org/onlinecourses
American Museum of Natural History
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California University of Pennsylvania
Designed for elementary and middle level teachers, Cal U’s online masters degree focuses on teaching inquiry across the STEM disciplines. Each course in the 30-credit program also develops your teacher leadership skills so you can take your career to the next level.

Mississippi State University
Earn a Master of Science degree in geosciences via distance learning through the Teachers in Geosciences program. Curriculum includes courses in geology, meteorology, climatology, oceanography, astronomy, hydrology, and environmental geoscience.

Montana State University - Bozeman
Online graduate credit courses for K–12 science teachers through National Teachers Enhancement Network, as well as online offerings for Masters of Science in Science Education. NSTA member discount.

University of Maryland
The online Master of Life Sciences degree, specially designed for science teachers, is a 30-credit interdisciplinary program offering concentrations in biology and chemistry.

University of Nebraska
Choose from more than 60 online programs for classroom educators and administrators, including master’s degrees in Biology, Entomology, Science for Educators, Science/Math Education and a graduate certificate in Insect Biology for Educators. Individual courses also available.

Wildlife Conservation Society
Online graduate courses provide K–12 educators an opportunity to examine life science through interactive simulations, videos, and presentations from WCS scientists and educators. Get the most up-to-date news from field experts and explore best practices in science education.

NSTA Online Short Courses
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As we move into the Northern Hemisphere summer months, the length of daylight increases at both ends—sunrise is earlier and sunset is later. During June, we have the earliest time for sunrise, the longest period of daylight, and the latest time for sunset (see the calendar in Figure 1 for dates and times). The calendar shows the dates and times as calculated for 40° north, and these times will vary based on latitude. The times are rounded off when using an online sunrise/sunset calculator; several days may show the same sunrise or sunset times and lengths (see the Sunrise Sunset link in Resources for a calculator). This is because the calculations for sunrise and sunset are rounded up and only shown using hours and minutes, not seconds. For example, on the Sunrise Sunset website, looking up Washington, DC, (39° north) will reveal a range of dates showing the same time because the calculations round off the seconds. However, the earliest sunrise (5:41 a.m. EDT) will be on June 14, the longest day will be on June 21 (14 hours, 54 minutes), and the latest sunset (8:33 p.m. EDT) will be on June 27. An interesting application for this information is to have students use the Sunrise Sunset website and determine not only their local times but also investigate and graph times and dates at other latitudes in the United States or the world.

One of the downsides to the increase in daylight hours and decrease in night hours is that there is less night sky to view. However, there is a celestial symmetry between the number of hours of daylight and night each season (Figure 1).

Another example of this celestial symmetry was discussed in this column last February, where it was pointed out that during the winter months, some summer stars and constellations are visible during the predawn hours as they rise above the southeastern horizon (see Resources). After about one-half year of revolution around the Sun and moving into the summer months, we have “flipped” the sky so that the stars of winter’s predawn skies are now the evening stars of summer, and the stars of the winter skies are now in the predawn skies over the southeastern horizon as they rise.

**Summer viewing**

Despite fewer night hours, this summer will be a good one for planet observing. All of the visible planets will brighten the morning and evening skies as they jockey for position, moving past one another and two bright open star clusters. Interestingly, much of the morning and evening planetary action will take place in the same general region of the sky—something centered on the Gemini Twins.

Open star clusters such as M35 in Gemini and M44 in Cancer are collections of stars held together by their mutual gravitational fields and are arranged in a loose-appearing grouping of up to a few thousand stars. Stars within an open cluster all formed at about the same time out of giant molecular clouds of gases; as a result, they are all about the same approximate age. M35 is at a distance of about 2,800 light-years and covers a space about the size of the full Moon, while M44 is about 600 light-years distant and is twice as bright as M35, so it is more easily seen. Both open star clusters are wonderful stellar objects when viewed with binoculars or low-power telescope eyepieces.

**Mercury** will begin the summer months near the feet of the Gemini Twins and on June 1 will be closest to the open star cluster M35. As Mercury continues moving eastward, it will pass Venus on June 18 before curving back toward the Sun and inferior conjunction on July 9. Following inferior conjunction, Mercury will reappear in the morning skies toward the middle of July as it moves westward along the stars of the Gemini Twins. On the mornings of August 10 and 11, Mercury will pass by the open star...
cluster M44, also known as the Beehive cluster, in Cancer. By June 24, Mercury will be on the opposite side of the Sun in superior conjunction.

**Venus** will move into the evening skies in June. As it moves eastward, Venus will travel from the feet of the Gemini Twins through the boundaries of Cancer the Crab and Leo the Lion. By summer’s end, Venus will be near the blue-white star Spica midway across the boundaries of Virgo the Harvest Maiden. Use binoculars to see Venus pass by the open star cluster M35 in Gemini; it will come the closest on June 4. On July 2 and 3, Venus will pass by another open star cluster, M44 (the Beehive cluster), in Cancer.

**Mars** will be a morning planet during the summer months, rising ahead of the Sun. However, Mars will not be easily visible until mid-July, when it will be rising about an hour before sunrise. During the summer, Mars will follow nearly the same path as did Venus. Mars will be moving eastward as it traverses the stars of the Gemini Twins. On the mornings of August 16 and 17, use binoculars to see Mars pass by the open star cluster M35. A few days later, Mars will pass by the planet Jupiter.

**Jupiter** will be low over the western horizon during the first week of June just below Venus and Mercury. However, Jupiter will move into superior conjunction, on the opposite side of the Sun, on June 19 and will not be visible until it starts becoming more so as a morning planet toward the latter half of July. Just before sunrise on the first few days of July, Jupiter will pass by the open star cluster M35 near the feet of the Gemini Twins. Watch for a close conjunction between Jupiter and Mars on the morning of July 20.

**Saturn** will be visible throughout the night hours as it rises approximately at local sunset time in June. By the end of August, however, Saturn will be setting at about the time of local sunset. This ringed planet spends the three summer months within the boundaries of the constellation Virgo the Harvest Maiden. Saturn will be about 15° east of the bright blue-white star Spica.

The **Perseid meteor shower** is an annual event that happens each August as the Earth passes through debris left behind by Comet 109P/Swift-Tuttle. The Perseids will begin when the Earth enters the fringes of the comet’s debris cloud on July 17, peak on August 12, and end as we exit the debris cloud around August 24. At the peak, this meteor shower can average around 200 meteors per hour; however, seeing that number would require relatively dark skies. This year will be a good year for viewing the meteor shower because the Moon will be in the waxing crescent phase during the peak night in August and will have set hours before the “radiant” for the meteor shower rises in the northeast. The radiant of a meteor shower is the central spot, or place, within a constellation from which the meteors appear to radiate outward. The constellation Perseus the Hero will rise just before midnight local time; best viewing will be a couple of hours before sunrise, as the part of Earth you are viewing from rotates, so you are seeing the meteors head-on as they enter the upper atmosphere.

**Summer reads**

Whenever I recommend reading material, I am reminded of a conversation between two characters on the TV show *Cheers*: “As a kid my nickname was Red.” “Because your hair was red?” “No, I read a book!” Hopefully, as teachers we are able to encourage students to read more than one book. Given the proliferation of handheld devices capable of displaying reading material, I’ve compiled a small collection of online and e-books that will be of interest to you and your students. Many of the books are on websites that in-

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**FIGURE 1** Approximate dates and times of sunrise and sunset and lengths of daylight and night

<table>
<thead>
<tr>
<th>Season and date</th>
<th>Sunrise</th>
<th>Sunset</th>
<th>Daylight (hours)</th>
<th>Night (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer: June 21</td>
<td>4 a.m.</td>
<td>8 p.m.</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>Autumn: September 21</td>
<td>6 a.m.</td>
<td>6 p.m.</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Winter: December 21</td>
<td>8 a.m.</td>
<td>4 p.m.</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>Spring: March 21</td>
<td>6 a.m.</td>
<td>6 p.m.</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

Note: The number of hours are rounded, use Eastern Standard Time, and set a general date for each season.
includes lesson plans and other related resources. Most of these are PDF files; as such, they can be read on nearly every handheld device. Some of the books are also available through the iTunes store specifically for the iPad. In this format, the books are interactive and include videos and other multimedia embedded within the book. (See Resources for additional reading material and reading list information.)

### June

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Neptune begins retrograde motion</td>
</tr>
<tr>
<td>8</td>
<td>New Moon</td>
</tr>
<tr>
<td>9</td>
<td>Moon at apogee (252,587 mi. [406,500 km])</td>
</tr>
<tr>
<td>10</td>
<td>Moon near Venus</td>
</tr>
<tr>
<td>12</td>
<td>Mercury at east elongation</td>
</tr>
<tr>
<td>14</td>
<td>Earliest sunrise (5:41 a.m. EDT)</td>
</tr>
<tr>
<td>16</td>
<td>First quarter Moon</td>
</tr>
<tr>
<td>18</td>
<td>Moon near Spica</td>
</tr>
<tr>
<td>19</td>
<td>Jupiter at superior conjunction</td>
</tr>
<tr>
<td>20</td>
<td>Mercury near Venus</td>
</tr>
<tr>
<td>21</td>
<td>June solstice (1:04 a.m. EDT)</td>
</tr>
<tr>
<td>23</td>
<td>Moon at perigee (221,830 mi. [357,000 km])</td>
</tr>
<tr>
<td>24</td>
<td>Moon occultation of Pluto</td>
</tr>
<tr>
<td>25</td>
<td>Full Moon</td>
</tr>
<tr>
<td>26</td>
<td>Moon near Saturn</td>
</tr>
<tr>
<td>27</td>
<td>Latest sunset (8:33 p.m. EDT)</td>
</tr>
<tr>
<td>28</td>
<td>Last quarter Moon</td>
</tr>
<tr>
<td>29</td>
<td>Tunguska event (1908)</td>
</tr>
</tbody>
</table>

### July

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dwarf planet Pluto at opposition</td>
</tr>
<tr>
<td>3</td>
<td>Venus near Beehive star cluster</td>
</tr>
<tr>
<td>5</td>
<td>Earth at aphelion (94,508,19 mi. [152,096,155 km])</td>
</tr>
<tr>
<td>6</td>
<td>Henrietta Swan Leavitt’s birthday (1868)</td>
</tr>
<tr>
<td>9</td>
<td>Moon at apogee (252,587 mi. [406,500 km])</td>
</tr>
<tr>
<td>8</td>
<td>New Moon</td>
</tr>
<tr>
<td>9</td>
<td>Mercury at inferior conjunction</td>
</tr>
<tr>
<td>10</td>
<td><strong>Cassini</strong> flyby of Titan</td>
</tr>
<tr>
<td>15</td>
<td>First quarter Moon</td>
</tr>
<tr>
<td>16</td>
<td>Moon near Saturn</td>
</tr>
<tr>
<td>20</td>
<td><strong>Cassini</strong> flyby of Titan</td>
</tr>
<tr>
<td>21</td>
<td>Mars near Jupiter</td>
</tr>
<tr>
<td>22</td>
<td>Moon occultation of Pluto</td>
</tr>
<tr>
<td>23</td>
<td>Full Moon</td>
</tr>
</tbody>
</table>

### August

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Moon at apogee (252,152 mi. [405,800 km])</td>
</tr>
<tr>
<td>4</td>
<td>Moon near Jupiter</td>
</tr>
<tr>
<td>4</td>
<td>Asteroid Juno at opposition</td>
</tr>
<tr>
<td>6</td>
<td>New Moon</td>
</tr>
<tr>
<td>9</td>
<td>Moon near Venus</td>
</tr>
<tr>
<td>12</td>
<td>Moon near Spica</td>
</tr>
<tr>
<td>13</td>
<td>Moon near Saturn</td>
</tr>
<tr>
<td>14</td>
<td>First quarter Moon</td>
</tr>
<tr>
<td>17</td>
<td>Mars near Gemini the Twins</td>
</tr>
<tr>
<td>18</td>
<td>Moon occultation of Pluto</td>
</tr>
<tr>
<td>20</td>
<td>Full Moon</td>
</tr>
<tr>
<td>24</td>
<td>Mercury at superior conjunction</td>
</tr>
<tr>
<td>26</td>
<td>Neptune at opposition</td>
</tr>
<tr>
<td>28</td>
<td>Last quarter Moon</td>
</tr>
<tr>
<td>30</td>
<td>Moon at apogee (251,593 mi. [404,900 km])</td>
</tr>
<tr>
<td>31</td>
<td>Moon near Jupiter</td>
</tr>
</tbody>
</table>

### Resources

- Mars’s calendar—[www.planetary.org/explore/space-topics/mars/mars-calendar.html](http://www.planetary.org/explore/space-topics/mars/mars-calendar.html)
- Perseid meteor shower—[http://meteorshowersonline.com/perseids.html](http://meteorshowersonline.com/perseids.html)
- Sunrise Sunset—[www.sunrisesunset.com](http://www.sunrisesunset.com)

### E-books and PDFs

- *Cindi in Space* (a story in comic form about an android girl, her two dogs, and the CINDI mission [Counted Ion Neutral Dynamics Investigation] to study our upper atmosphere)—[http://cssepo.utdallas.edu/cindi-in-](http://cssepo.utdallas.edu/cindi-in-
comics-2/cindi-in-space-2.html
The classroom astronomer—http://classroomastronomer.toteachthestars.net
Earth as Art (a collection of pictures of our planet taken by several orbiting satellites)—www.nasa.gov/connect/ebooks/earth_art_detail.html
The first two of three-book series Think Scientifically, part of the Solar Dynamics Observatory’s literacy program—http://sdo.gsfc.nasa.gov/epo/educators/thinkscientifically.php
Free e-books—www.freebooksifter.com
Hanny and the Mystery of the Voorwerp (a comic book about the true story of a young Dutch girl, Hanny Van Arkel, who, in the summer of 2007, was examining galaxies as part of the Galaxy Zoo project when she discovered a mysterious object)—http://hannysvoorwerp.zooniverse.org/comic-index/comicbook
Hubble and Webb space telescope books—http://hubblesite.org/ibooks
Lawrence Hall of Science books for students—www.globalsystemsscience.org/studentbooks
PBS Learning Media—http://pbslearningmedia.org
Science fiction stories with good astronomy and physics—www.astrosociety.org/edu/resources/scifprint.html
Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) comic books about solar-terrestrial physics—www.yorku.ca/scostep/?page_id=366
What Are Cosmic Rays? (a comic book produced by the Solar-Terrestrial Environment Laboratory, Japan’s Nagoya University, and SCOSTEP)—www.stelab.nagoya-u.ac.jp/site-www1/pub/nanda/cosmicrays_e.pdf
What Are the Polar Regions? (a comic book produced by the Solar-Terrestrial Environment Laboratory, Japan’s Nagoya University, and SCOSTEP)—www.arvindguptatoys.com/arvindgupta/scostep-polar.pdf

Bob Riddle (bob-riddle@currentsky.com) is a science educator in Lee’s Summit, Missouri. Visit his astronomy website at www.currentsky.com.

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**The Case for STEM Education**

*Challenges and Opportunities*

**Grades K–12**

If you’re concerned with science, technology, engineering, and mathematics initiatives, this book is a must-read. Author Rodger Bybee outlines the challenges facing STEM education while offering several ideas you can use to develop action plans for implementing STEM instruction. Teachers, administrators, methods professors, and education leaders at all levels will benefit from this book.

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**Everyday Science Mysteries**

*Stories for Inquiry-Based Science Teaching*

**Grades K–8**

Everyone loves a good mystery—and thousands of teachers love the way the Everyday Science Mysteries series gets K–8 students engaged in real experimentation about real science content. NSTA’s three new releases in this bestselling series each focus on a specific content area—Earth and space science, physical science, or biological science.

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**Scientific Argumentation in Biology**

*30 Classroom Activities*

**Grades 6–12**

Like three guides in one, *Scientific Argumentation in Biology* combines theory, practice, and biological content. It provides 30 activities you can use when teaching students how to propose, support, and evaluate claims; validate or refute them on the basis of scientific reasoning; and craft complex written arguments. You’ll find *Scientific Argumentation* to be an ideal way to help your students learn standards-based content, improve their practices, and develop scientific habits of mind.

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Perspectives
Research and Tips to Support Science Education, K–6

Perspectives offers a time-saving way to learn what research tells you about teaching elementary science and applying the findings both inside and outside your classroom. It’s a collection of 27 “Perspectives” columns from Science and Children, NSTA’s award-winning elementary-level journal. The book comprises six science-specific sections, including general teaching goals, strategies to facilitate learning, student thinking and misconceptions, and your own professional development.

Member Price: $15.96 | Nonmember Price: $19.95

Integrating Engineering and Science in Your Classroom
Grades K–12

Next time you need an engaging STEM activity, you’ll be glad you have this collection to help you blend meaningful and memorable experiences into your lessons. Its 30 chapters feature STEM lessons and design challenges that involve everything from light sabers and egg racers to prosthetic arms and potatoes. These activities reinforce important science content while illustrating a range of STEM skills.

Member Price: $23.96 | Nonmember Price: $29.95

The NSTA Reader’s Guide to the Next Generation Science Standards

The key to unlocking the full potential of the NGSS is a deep understanding of the interrelationship of its core ideas, scientific and engineering practices, and crosscutting concepts. This brief and easy-to-use Reader’s Guide offers anyone with a vested interest in improving the quality of science education the tools they need to absorb the new standards and begin to implement them, effectively, into classroom practices.

Member Price: $8.76 | Nonmember Price: $10.95

To place an order or download a free chapter, visit www.nsta.org/store
This collection of 28 activities was written by a team from Miami (Ohio) University with funding from the National Science Foundation and other sources. Although many of the activities may be familiar to veteran teachers, the complete directions and thorough correlations to national standards included here make these lessons especially convenient, accessible, and practical.

In the introduction, the authors emphasize the use of authentic experiences; the importance of claims, evidence, and models; and the distinction between demonstrations and individual, hands-on explorations. As promised in the title, the activities seek to engage students through humor and storytelling, and toys like hand boilers and whoopee cushions are used to generate interest. The activities are indexed by concept and correlated to both middle and secondary National Science Education Standards, but many could easily be modified for lower grades.

Safety is emphasized throughout. Tips, instructional strategies, and explanations are included.
for the teacher, and answers to student questions are clearly presented. PDF and editable files are currently available online to use as student activity sheets. Either with Volume 1 or on its own, this would be an ideal addition to an individual teacher’s library and an asset to a preservice program to help teachers develop skills for fostering inquiry.

Daniel Kujawinski

Success in Science through Dialogue, Reading and Writing

With the arrival of the Common Core State Standards and A Framework for K–12 Science Education, secondary school science teachers are faced with a challenging question: How do we integrate language arts and argument-based instruction (as advocated for in the Common Core and Framework) into our science curricula to help students become “critical consumers” of scientific information? Fortunately, there is a resource that comes to the rescue.

This book offers an innovative framework to meet the new national standards while helping disengaged students comprehend science texts and develop their proficiency in science. The authors

Try this TOPS IDEA!

Clock Pendulum

1. Tie an arm’s length of thread to a paper clip.
2. Lightly fold a small piece of masking tape over the middle.
3. Slide the thread through the tape until you find the length where your pendulum swings exactly one cycle each second.
4. Measured to the center of the bob (the paper clip), how long is your pendulum clock? Can you accurately time one minute with it?

OBJECTIVE
To make a pendulum that ticks like a clock, at 60 cycles per minute.

SET-UP
Cover wall clocks. Ask students to be seated and put away all timepieces (you will be the only timekeeper). Announce a contest: students should stand up when they guess that one minute has passed from the moment you say “GO!” Note who stands closest to the mark, but don’t announce the winner until all are standing. Then hand out copies of the lab above. Students might repeat this contest at the end of this lab (see wrap-up).

LAB NOTES
Copy the lab for each student or lab team.
Notes 2–3. Tape folded over thread makes an ideal pendulum pivot: hold it while the pendulum swings beneath. The thread stays put until you slide it to a new pendulum length. By trial and error, students find the length that counts 60 seconds with 60 swings.

ANSWERS
4. A one-second pendulum measures 24.8 cm from the edge of the tape tab to the middle of the clip.

WRAP-UP
Have students sit again, then ask them to stand at precisely one minute by counting their pendulum cycles. They will likely all stand together.

EVALUATION
Q. A grandfather clock runs too slow. How would you adjust its pendulum bob to improve its timing?
A. Shorten the pendulum to speed up the clock. An adjustable nut on the bob generally allows this.

EXTENSION
Develop a pendulum that makes 1 swing (half a cycle) each second. How many times longer is this than your 1-cycle-per-second pendulum? Ideal pendulums 4 times longer swing at half the frequency.

MATERIALS
• Thread, scissors, a paper clip, masking tape, and a centimeter ruler.
• A clock or timepiece that shows seconds.

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offer a Science Literacy Framework (SLF) that starts with an engaging experience (an inquiry, a lab, or collecting and analyzing data), then follows that up with (1) a purposeful reading assignment from the textbook to find out what others know about the question being investigated, (2) a productive dialogue where students make a claim and defend their assertions with evidence, and finally (3) a meaningful writing activity where students write an explanation to summarize their findings.

Even those who say, “Wait a minute, I’m not an English teacher,” will find that Success in Science is an understandable and well-written support that provides both (a) research stating why students benefit from structures that assist them to talk out their understandings and opinions and then summarize them in written form as evidence of their thinking, and (b) sample activities and planning pages for fitting individual lessons to the suggested framework.

The book is organized into nine chapters. Chapter 1 is a brief vignette of a teacher using the SLF, while Chapters 2 and 3 present and explain the framework. Chapter 4 offers examples of lessons in biology, Earth science, and physical science that elaborate on the framework, and Chapter 5 deals with the all-important issue of motivating students to read and write based on topics that capture their interest and imagination. Chapters 6, 7, and 8 provide techniques to effectively help students make their thinking more explicit through dialogue and writing, such as Talking Sticks, Think-Pair-Share, Paired Verbal Fluency, Four Corners, Paraphrase Passport, and Dialogue Dots. Lastly, Chapter 9 lays out the “big picture” in restructuring science curricula to the proposed framework. 

In his popular 1964 song, Bob Dylan sang, “You better start swimmin’ or you’ll sink like a stone—for the times they are a-changin’.” For science teachers the times they are a-changin’. Gone are the days of straight lecture about and recitation of science facts and figures.

Tomorrow’s science teachers need to be skilled in strategies that build comprehension in reading and writing while helping students make and defend arguments and understand core ideas. Success in Science through Dialogue, Reading and Writing delivers means and methods to bring about the changes prescribed by the Common Core initiative and A Framework for K–12 Science Education.

Making Sense of SCIENCE: Matter for Teachers of Grades 6–8

At first glance, this pair of volumes may seem intimidating—especially for the elementary- or middle-level teacher who has suddenly come face-to-face with the strengthened physical science standards in both the Common Core State Standards and the Next Generation Science Standards. It is described as a semester-long professional development course, and it certainly could be that. The authors point out that the material is teacher centered, collaborative, rigorous, and standards based, focused on both learning and teaching with recognition of metacognition. But most importantly, the authors have tried to produce a guide that is “satisfying, worthwhile, and fun.” That’s why this compendium of methods and materials, along with its Facilitator Guide, has the potential to be much more—a very valuable reference for teachers who couldn’t find the time to take a formal course or the core of a discussion group.

For each of five content areas (“Properties of Matter,” “Particles of Matter,” “Changes in Matter,” “Atomic Structure,” and “Matter in Action”), the book offers extremely practical information on both content and methods. It also provides a guide to looking at student work, including mental models, learning gaps, and how to analyze and modify tasks based on how a teacher is informed by assessment. “Teaching Cases” describe complete sequences of instruction (rather than stand-alone activities). There are repeated examples of both mathematical and literacy applications for each concept, along with guides for evaluating student work. Pages of simple diagrams make the concepts clear and distinguish between correct and incorrect student ideas.
Yes, the questions at the end of each of the five units sound a lot like they belong in a graduate course; however, they are also valuable as prompts for less formal discussion in the teachers lounge of how students are doing or during release time for professional development. It’s easy to imagine the average teacher or community of educators using this book in many other ways than formal course work. If, for example, a staff identified one area of content in which a specific grade level was having difficulty on a standardized assessment, that section might be the focus of an effort that was both thorough and extremely effective.

For those teachers who are looking at the heightened expectations in physical science at the elementary and middle level, this compendium is key. While it doesn’t come in easy bites, the message of the entire program is “Relax. You can do this. Here’s how.”

Juliana Texley

The Case for STEM Education: Challenges and Opportunities
By Rodger W. Bybee.

The value of STEM education lies not in an appreciation of science, technology, engineering, and math, but in an aspiration for something greater. Author Rodger Bybee makes this point with repeated references the Sputnik era and the space race to model how a motivating force creates sustained change. During the decade between Sputnik and landing on the Moon, the goal was clear: to invest resources in education and development in order to land people on the Moon within 10 years. The goal was measurable and time delimited. With the current STEM initiative, our students, teachers, and stakeholders need to aspire to something greater, to a common STEM framework with concrete goals. The author proposes specific avenues of development in the areas of health, energy, environment, and the use of natural resources with improvements in a 20-year window.

This text is an amazingly high-level presentation of the “challenges and opportunities” afforded to our children by President Obama to NCLB. A by-product of STEM initiatives should be improved test scores so that our international rank rises above mediocre. Additionally, educators should continue to impress upon our children the need for 21st-century skills, such as creative problem solving, communication, virtual solutions, and systems thinking, so the United States can continue to compete against strongholds such as Singapore, Finland, Hong Kong, and other countries that are actively developing young minds to lead in these areas in the future.

While the president of the United States can motivate by delivering speeches about STEM initiatives, it is up to state and district agencies to develop the policies, programs, and classroom practices that will help our children. Yet the goal is greater than knowledge—it is the application of knowledge, which will have sustained economic and social benefits. As the title of this book implies, it is an exciting time to be an educator, because with this historic challenge, we have a monumental opportunity. The Case for Stem Education is a necessary reference for anyone involved in negotiating the policies and practices that will affect teachers and students into the 21st century.

David Tumbarello

Perspectives: Research & Tips to Support Science Education, K–6

While many educators may wonder if what they are doing in the classroom is the best way to help students succeed, busy teachers rarely have time to review research about science teaching. This volume supports great science teaching and provides the research-based advice needed to improve teaching in an easily accessible way so that all educators can be the very best at what they do in the science classroom.

This volume contains 27 columns originally published in Science and Children, a journal that supports teaching for elementary
Grades. The columns are grouped into six sections that cover topics that relate to all elementary teachers: “Teaching Goals”; “Strategies to Facilitate Science Learning”; “Teaching Science and Other Disciplines Together”; “Student Thinking and Misconceptions”; “Society and Science Learning”; and “Developing as a Teacher.”

Each of the columns starts with a real-life scenario expressed by a teacher. For example, in the section on student thinking and misconceptions, a very important topic, the first column is “Assessing and Addressing Student Science Ideas.” In the scenario in this particular column, a colleague is concerned that following a science unit, several students still have “wacky ideas” about the concepts they were taught. Reading further, one learns what research says about these “wacky ideas,” which are sometimes called alternative conceptions, naive conceptions, or misconceptions. The author explains how to identify those ideas and what misconceptions to expect, and concludes with strategies that are useful in addressing these misconceptions. Following this short, four-page column are 12 solid research resources for further reading.

Each chapter is formatted identically so readers have concise information quickly available to them. Professors of future science educators, teachers both new and experienced, supervisors of groups of teachers, and educators in general will find that this volume provides proof that science in elementary school is necessary. This book also includes the most effective, current, research-based approaches for science in the elementary classroom. I highly recommend it to all educators.

Adah Stock

Show Me What You Know: Exploring Student Representations Across STEM Disciplines

Teachers who wish to learn more about how their students develop the ability to “represent” the content they are learning would be well served by reading this book. It examines how students across different ages and disciplines produce and use representations such as graphs, drawings, and other products in order to understand their experiences. The authors who contributed to this collection use the extensive research that has been done to show the importance of understanding how representations can be crucial in the development of students’ ability to understand all of the STEM disciplines.

The book will be especially useful to middle and secondary teachers as they try to build on students’ prior experiences. “Show Me What You Know” is broken into four sections, each discussing a different aspect of representations. The first part shows how learners develop the skills for sharing their experiences and focuses on how young children create symbols to represent quantitative data. This is followed by sections that explain how students become fluent at using different representations, especially graphs, and why they eventually choose certain ones to externalize their experiences. The last part of the book discusses how representations can be used to support students in engaging with new material and challenging themselves to better communicate their ideas. This section also explores how children begin to manipulate representations with the help of “scaffolds” and “supports” that they have developed.

One of the strengths of the book is the comprehensive nature of the material presented. The various contributors provide extensive examples of students’ graphs, charts, and drawings to help the reader make sense of this challenging topic. They also provide extensive references at the end of each chapter.

One of the biggest challenges that teachers in the STEM disciplines face daily is helping their students to make sense of concepts. By better understanding how students develop their ability to make representations, whether through graphs, by making drawings, or using some other tool, teachers could better gauge how well they are learning.

Thomas Brown
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Can you identify our Mystery Photo?

How to submit a guess
In each issue of Science Scope, we will publish a science-related image for your students to identify. When an image is published, teachers can submit a guess on behalf of their class through our website, by e-mail at sciencescope@nsta.org (please include “Mystery Photo” in the subject line), or by mail (Science Scope, Mystery Photo, 1840 Wilson Boulevard, Arlington, VA 22201). Those classes that correctly identify the Mystery Photo of the month will be eligible for a drawing to receive an item of their choice from NSTA’s Science Store.

Only one entry per class per contest will be accepted. Please be sure to include the instructor’s name, subject taught, grade level, and name of your school along with your guess. The names of the contest winners, as well as the solution to the Mystery Photo, will be published in the following issue’s column.

Last month’s answer: Nikola Tesla (1856–1943)

The winner of our April/May 2013 Mystery Photo Contest was Britt Weatherby’s sixth-grade science class at Donna Shepard Intermediate School in Mansfield, Texas. Britt and his class will receive one item of their choice from the NSTA Recommends catalog (www.nsta.org/pdfs/2011springcatalog.pdf).

This is a detail from a 500 Dinar bill, circulated in the former Yugoslavia to commemorate “the patron saint of modern electricity.” The image is based on a statue erected in Niagara Falls, New York. After seeing a picture of the famous falls as a boy, Tesla told his uncle he wanted to put a wheel under the falls to harness the power of the moving water. Tesla and George Westinghouse built the world’s first hydroelectric power plant at the falls in 1895. Tesla is also famous for his work with and promotion of alternating current, as well as the development of the Tesla coil.
Ready for Your Next Move?

Career Advancement Made Easy
The NSTA Career Center is the ideal place to be seen by employers who are specifically looking for science teaching professionals. Whether or not you are actively looking for new employment, it makes sense to post your resume on the NSTA Career Center—because you never know what opportunities may be out there looking for you. Also, checking the job listings is a great way to see what is hot and what is not in the job market, and whether your particular skills are among those most in demand.

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Saved jobs capability—Save up to 100 jobs to a folder in your account so you come back to apply when you are ready.

The NSTA Career Center makes finding the perfect job easy.
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Project-Based Inquiry Science (PBIS) empowers your students to think like engineers.

More than any other middle school program, the PBIS Project-Driven Inquiry approach exemplifies the use of STEM in the classroom. Throughout PBIS, students use the Engineering Design Cycle to problem-solve real-world projects and build the skills they will need to be successful in the 21st century:

- working collaboratively,
- communicating plans and ideas,
- building on the work of others,
- collecting, organizing, and analyzing data,
- observing and interpreting,
- using evidence to support claims,
- thinking critically.